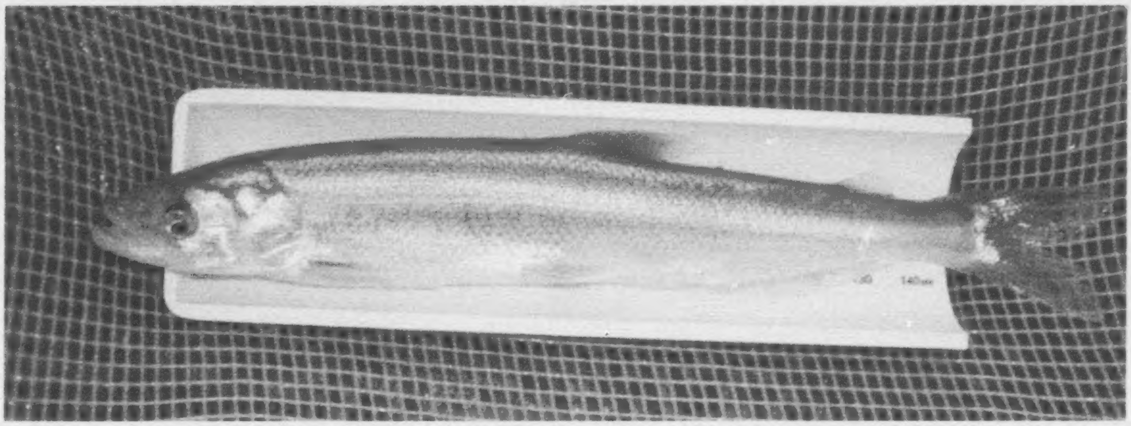
COSEWIC
Assessment and Status Report

on the

Eulachon
Thaleichthys pacificus

Nass / Skeena Rivers population
Central Pacific Coast population
Fraser River population

in Canada



Central Pacific Coast population - ENDANGERED
Fraser River population - ENDANGERED
Nass / Skeena Rivers population - THREATENED
2011

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

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Eulachon — Photograph by Nigel Young.

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COSEWIC
Assessment Summary

Assessment Summary – May 2011

Common name
Eulachon - Nass / Skeena Rivers population

Scientific name
Thaleichthys pacificus

Status
Threatened

Reason for designation
This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. Current run sizes in the Nass/Skeena area are estimated to be less than 10% of what they were in the 1800s when annual First Nation harvests were in the range of 2000 t. Recent data from this area indicate the population is declining and the level of abundance in adjacent areas has declined substantially in the recent past.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Threatened in May 2011.

Assessment Summary – May 2011

Common name
Eulachon - Central Pacific Coast population

Scientific name
Thaleichthys pacificus

Status
Endangered

Reason for designation
This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. All of the populations in the Central Pacific Coast area are substantially lower than what supported large First Nations fisheries in the 1800s and before. Each river for which there are records has experienced drastic declines in run size, some to the point of virtual extirpation including the Kitimat, Kemano, Bella Coola, and those in Rivers Inlet. Substantial declines have also been documented for the Kingcome and Klinaklini Rivers; however, there remain modest returns in these areas.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Endangered in May 2011.

Assessment Summary – May 2011

Common name
Eulachon - Fraser River population

Scientific name
Thaleichthys pacificus

Status
Endangered

Reason for designation
This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. This population's spawning biomass reached a historic low of only 10 t in 2008. The long -erm average spawning biomass on the Fraser River may have been about 1000 t. Based on the available spawning stock biomass time series, the 10-year decline rate was estimated to be 98%. The single small spawning area constitutes a single location.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Endangered in May 2011.

COSEWIC
Executive Summary

Eulachon
Thaleichthys pacificus

Nass / Skeena Rivers population
Central Pacific Coast population
Fraser River population

Wildlife species information

The Eulachon (*Thaleichthys pacificus*) is a species of smelt (Family Osmeridae, Order Osmeriformes). Eulachon are small fish, usually less than 20 cm total length. They resemble small Pacific salmon, having an adipose fin and long anal fin. Eulachon migrate to fresh water to spawn, but do not penetrate far upstream. They are, however, mainly a marine species, spending over 95 percent of their lives in the sea. Juvenile Eulachon are difficult to distinguish from other smelt species but in adults there is a distinctive characteristic in the form of a group of concentric lines or 'striae' on the gill cover (operculum).

Distribution

Within the entire range of Eulachon, from northern California to the eastern Bering Sea, there may be fewer than 100 rivers that support regular spawning runs. In British Columbia (BC) they occur in at least 38 rivers but many of these do not have regular spawning runs. A limited amount of genetic research indicates that there is reproductive isolation among some populations. These differences coupled with differences in run timing and location of source waters for Eulachon rivers suggest the species has 3 designatable units in Canada; the Nass/Skeena, the Central Pacific Coast, and the Fraser river.

Habitat

Throughout their range Eulachon spawn mainly in coastal rivers that are associated with glaciers or snowpacks and which contribute to strong spring freshets. There are no established populations spawning in rivers draining coastal islands, such as Vancouver Island, or any others in BC. Mildly adhesive eggs are deposited in the spring, on the river bottom sediments. In most rivers the eggs may move during incubation, so spawning habitats within rivers may encompass much of the river bottom. Incubation time is temperature-dependent and they incubate for about 2-8 weeks in the lower reaches of rivers. Immediately after hatching, yolk sac larvae are rapidly flushed into coastal estuarine waters. In the sea, Eulachon are found on shelf waters usually close to the bottom, often in depths of 50-200m.

Biology

Eulachon have exceptionally high lipid content, with about 20% of the wet weight being fatty tissue. This may be the highest of any known marine fish species. Generally Eulachon go unnoticed during the marine phase of their lives except when they are taken incidentally by trawl gear. The factors controlling their marine distribution are not understood. There are few morphological differences among populations throughout their range. Eulachon are semelparous and most spawn at age 3.

Population sizes and trends

There are several indices of Eulachon abundance within Canadian waters including annual surveys, fishery catch per unit effort, and indices from offshore surveys that monitor shrimp populations. There is convincing evidence of a sharp downward trend in most Eulachon runs during the last 30-40 years. Eulachon spawning runs in several rivers are virtually extirpated; most others are severely depleted. In contrast, abundance indices from offshore shrimp surveys indicate that total Eulachon abundance is considerably greater than that found in rivers. There is no satisfactory explanation for this difference in abundance estimates between rivers and offshore areas. However, the marine indices include a mixture of at least two pre-spawning age classes that will be exposed to marine mortality for one to two years. It is clear that Eulachon do not spawn in the open sea and that estimates of offshore abundance are not reliable indicators of spawning abundance in rivers. If population trends in rivers are considered over a longer term (e.g., a century or more) it is clear that most Eulachon spawning runs in traditional areas are now only remnants (less than 10%) of their past abundances.

Threats and limiting factors

Eulachon are mainly a marine species, spending more than 95% of their lives in the sea and only using freshwater during spawning, egg, and larval stages. There is some evidence of habitat degradation in some rivers due to dredging, industrial pollution, and impacts of the forest industry. However, it is unlikely that such threats would explain the nearly synchronous coast-wide decline of Eulachon that occurred in the early 1990s, especially in rivers with virtually pristine spawning habitats. In-river Eulachon fisheries are generally small and many have been suspended in some areas due to low abundance. However, continued fishing in areas where run sizes are severely depressed may pose a threat. On the other hand, the discontinuity between offshore indices of juvenile Eulachon abundance and indices of spawning abundance in coastal rivers suggests that variations in marine survival may be an important threat.

Eulachon survival at sea could be affected by predation, fishing activities that target other species, and changes in ocean climate. Because of their high lipid content, Eulachon would be a preferred prey species for many predators, including fish, marine mammals and seabirds. It is unlikely that changes in feeding habits of a single predator species could account for the nearly synchronous coast-wide decline of Eulachon that occurred during the mid-1990s. Fishing gear, especially bottom trawls, sometimes encounter Eulachon resulting in substantial bycatch, and therefore bycatch has been implicated in the decline. However, such bycatch is small relative to Eulachon biomass estimates in the sea. Systematic change in the ocean climate in recent decades cannot be excluded as a plausible explanation for some of the observed reduction in Eulachon abundance, but the evidence for this is circumstantial. It is clear that Eulachon populations in the southern parts of their range, which might be the most vulnerable to climate change, are the most severely affected. However, the biological mechanisms that would lead to difficulties in southern populations are not clear.

Special significance

The Eulachon has a unique and vitally important place in most First Nations communities on the British Columbia coast. The products of Eulachon harvest include fresh, dried, smoked, salted, and frozen whole fish; however, the product of greatest cultural, economic, nutritional, and social value is indisputably called ‘grease’ or the oil rendered from the fish. Distributed widely in potlatches, traded with neighbouring Nations, and relied upon for its wealth of nutritional and medicinal uses, grease and grease-making has long been a tradition in almost all First Nations with spawning rivers located in their traditional territory. The disappearance and decline of this resource is an immense loss to First Nations.

Existing protection, status, and ranks

The Province of British Columbia website on endangered species (http://a100.gov.bc.ca/pub/eswp/esr.do?id=14828) 'blue' listed Eulachon in 2000 and maintained the listing when it was reviewed in 2004. It is not clear if this listing has resulted in any action to address the imminent threats.

Eulachon are not listed under the international ICUN Redlist (International Union for Conservation of Nature and Natural Resources) http://www.iucn.org/about/.

On March 16, 2010, the United States announced that it was listing the southern Eulachon DPS (distinct population segment) as threatened under the ESA (Endangered Species Act). Details are available at: http://www.nwr.noaa.gov/Other-Marine-Species/Eulachon.cfm.

Since 1995 Fisheries and Ocean Canada (DFO) has under-taken five specific activities to protect Eulachon: (i) suspension of commercial Eulachon fisheries in the Fraser River; (ii) suspension of dredging during the Eulachon spawning season in the lower Fraser River; (iii) closure of the shrimp fishery in Queen Charlotte Sound; (iv) adoption of 'Eulachon action levels' by DFO management that warn of possible shrimp fishing closures when the cumulative Eulachon bycatch level is achieved; (v) requirement of mandatory 'BRDs' – or 'bycatch reduction devices' installed in shrimp trawls to reduce fish by-catch.

TECHNICAL SUMMARY – Nass/Skeena population

Thaleichthys pacificus	
Eulachon	Eulakane
Nass/Skeena population	Population Nass/Skeena
Range of Occurrence in Canada : Pacific coast	

Demographic Information

Generation time (average age of parents in the population)	3 yrs
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 or 5 years, or 3 or 2 generations]. *One study reported no decline in the 3-generation window. Analysis of the CPUE data from the First Nations fisheries indicated a decline of 48% over 3 generations. The Nass River fishery remains active and is currently the largest in BC. However, the current run size is less than 10% of the runs in the 1800s that supported substantial First Nations fisheries.*	Uncertain, one study indicates recent stability while the fishery data indicate a decline of 48%.
Projected or suspected reduction in total number of mature individuals over the next 10 years.	NA: projections not carried out
Estimated, percent reduction in total number of mature individuals over any 3 year period, over a period including both the past and the future.	Decline likely to continue
Are the causes of the decline clearly reversible?	Unlikely
Are the causes of the decline understood?	No
Have the causes of the decline ceased?	No
Projected trend in number of populations	Unknown
Are there extreme fluctuations in number of mature individuals?	No
Are there extreme fluctuations in number of populations?	No

Extent and Area Information

Estimated extent of occurrence	Unknown
Observed trend in extent of occurrence	Unknown
Are there extreme fluctuations in extent of occurrence?	Unknown
Index of area of occupancy (IAO)	Unknown
Observed trend in area of occupancy	Unknown
Are there extreme fluctuations in area of occupancy?	Unknown
Is the total population severely fragmented?	Unknown
Number of current locations	Unknown
Trend in number of locations	Unknown
Are there extreme fluctuations in number of locations?	Unknown
Trend in quality of habitat	Stable, possibly declining

Number of mature individuals in each population

Population (population estimate based on approximate estimates of t of SSB divided by a mean weight of 40 g per spawning fish).	**N Mature Individuals**
Based on a SSB of 400 t and mean wt of 40 g	10,000,000

Quantitative Analysis

Not done	

Threats (actual or imminent, to populations or habitats)

Eulachon in this area might be impacted by local road-building operations but this risk would be relatively slight. Some forest industry impacts might occur, but would not be exceptional compared to other locations. There is probably some risk of impacts from trawl fisheries in adjacent waters. In-river removals are also a threat.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Populations in Southeast Alaska are considered to be in poor condition as are other populations in Canada. Little is known about linkages between Eulachon populations across the Canada/U.S. (Alaska) border	
Is immigration known?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Not assessed

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** A2b+4b
Reasons for designation: This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. Current run sizes in the Nass/Skeena area are estimated to be less than 10% of what they were in the 1800s when annual First Nation harvests were in the range of 2000 t. Recent data from this area indicate the population is declining and the level of abundance in adjacent areas has declined substantially in the recent past.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened under A2b+4b as the spawning biomass is inferred to have declined over the past 10 years based on CPUE data and the decline is expected to continue into the future and the causes are not yet understood.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small Population or Restricted Distribution): Not applicable.
Criterion E (Quantitative Analysis): Not done.

TECHNICAL SUMMARY – Central Pacific Coast population

Thaleichthys pacificus	
Eulachon	Eulakane
Central Pacific Coast population	Population centrale
Range of Occurrence in Canada: Pacific coast	

Demographic Information

Generation time	3 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	NA
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 10 years.	Virtual extirpation of spawning runs in the Kitamat, Kemano, Bella Coola Rivers as well as runs in the Rivers Inlet area. Substantial (> 50%) declines in other rivers based on qualitative data.
Projected or suspected reduction in total number of mature individuals over the next 10 years.	NA: projections not carried out
Estimated, percent reduction in total number of mature individuals over any 10-year period, over a period including both the past and the future.	Decline likely to continue
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of populations?	No

Extent and Area Information

Estimated extent of occurrence	Unknown
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Unknown
Is the total population severely fragmented?	Unknown
Number of locations	Unknown
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] continuing decline in the index of area of occupancy?	Decline in number of spawning rivers
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Yes
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	Unknown
Are there extreme fluctuations in extent of occurrence?	Unknown
Are there extreme fluctuations in index of area of occupancy?	Unknown

Number of mature individuals in each population

Populations	**N Mature Individuals**
Kitimat River (Table 6)	Virtually 0 (2009)
Kemano River (Table 7)	Virtually 0 (2009)

Kitlope and other rivers – probably zero abundance	
Bella Coola River	Virtually 0
Rivers Inlet Rivers	Virtually 0
Kingcome Inlet	Significant but unknown numbers
Klinaklini River	375,000

Quantitative Analysis

	Not done

Threats (actual or imminent, to populations or habitats)

Eulachon have been exposed to industrial pollution from a pulp mill, domestic sewage outfall and waste from a salmon hatchery. Kemano River Eulachon have experienced changes in river discharge due to hydro development. Eulachon from these rivers may be impacted from trawl fisheries, especially in Hecate Strait and Queen Charlotte Sound. In-river removals also pose a threat.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Populations in Southeast Alaska and the Columbia River are considered to be in poor condition	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Unlikely

Current Status

COSEWIC: Not assessed

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2b+4b

Reasons for designation:
This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. All of the populations in the Central Pacific Coast area are substantially lower than what supported large First Nations fisheries in the 1800s and before. Each river for which there are records has experienced drastic declines in run size, some to the point of virtual extirpation including the Kitimat, Kemano, Bella Coola, and those in Rivers Inlet. Substantial declines have also been documented for the Kingcome and Klinaklini Rivers; however, there remain modest returns in these areas.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered under A2b+4b as quantitative data on run size in the Kitimat and Kemano Rivers indicate declines of over 90% in the past 15 years. These runs were virtually non-existent in the past few years. Qualitative information from the Bella Coola and Rivers Inlet areas suggest similar losses. Substantial declines have also been documented for the Kingcome and Klinaklini Rivers. The decline is expected to continue into the future. The cause of the decline is not understood.

Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable.

Criterion C (Small and Declining Number of Mature Individuals): Not applicable.

Criterion D (Very Small Population or Restricted Distribution): Not applicable.

Criterion E (Quantitative Analysis): Not done.

TECHNICAL SUMMARY - Fraser River population

Thaleichthys pacificus
Eulachon — Eulakane
Fraser River population — Population de la rivière Fraser
Range of Occurrence in Canada: Pacific coast

Demographic Information

Generation time	3 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	NA
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Decline of 98%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	NA: projections not carried out
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Decline likely to continue
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Area Information

Estimated extent of occurrence	Unknown
Index of area of occupancy (IAO) (Always report 2x2 grid value).	216 km^2
Is the total population severely fragmented?	No
Number of locations	1
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	Unknown
Are there extreme fluctuations in index of area of occupancy?	No

Number of mature individuals in each population

Population (population estimate based on approximate estimates of t of SSB divided by a mean weight of 40 g per spawning fish).	**N Mature Individuals**

Current spawning biomass 24 t	600,000

Quantitative Analysis

	Not done

Threats (actual or imminent, to populations or habitats)

Fraser River: Habitat damage from increasing industrialization in lower Fraser River (rip rap and other obstacles), dredging of spawning areas, offshore interception and bycatch in trawl fisheries, poaching, possible extreme marine mammal predation (the adjacent marine waters have seen a Harbour Seal population explosion that has resulted in the highest Harbour Seal density in the world), sensitive to climate change impacts on river discharge, temperature and flow rates.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? Populations in Southeast Alaska and the Columbia River in the U.S. are considered to be in poor condition as are other populations in Canada.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Not assessed

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2b+4b; B2ab(v)

Reasons for designation:
This short-lived semelparous species is extremely rich in lipid and spends over 95% of its life in the marine environment. This population's spawning biomass reached a historic low of only 10 t in 2008. The long-term average spawning biomass on the Fraser River may have been about 1000 t. Based on the available spawning stock biomass time series, the 10-year decline rate was estimated to be 98%. The single small spawning area constitutes a single location.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered under A2b+4b as the spawning biomass is estimated to have declined by 98% over the past 10 years. The cause of the decline is not understood.

Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered under B2ab(v) as the index of area of occupancy for spawning (216 km²) is lower than the threshold, there is only one spawning location and there is a declining trend in the number of mature individuals.

Criterion C (Small and Declining Number of Mature Individuals): Not applicable.

Criterion D (Very Small Population or Restricted Distribution): Not applicable.

Criterion E (Quantitative Analysis): Not done.

PREFACE ON ABORIGINAL TRADITIONAL KNOWLEDGE

Relatively little scientific and biological information about Eulachon in British Columbia (BC) was readily available prior to the mid-1990s. At that time Eulachon issues arose relative to the impacts of the planned Kemano Completion Project. The project would have diverted water into the Kemano, substantially affecting its discharge velocity, so there was a potential impact on Eulachon spawning in the river. There also was a sudden decline in the availability of Eulachon to a commercial fishery in the Fraser River. This prompted attention from the Department of Fisheries and Oceans (DFO) and led to the development of small research programs on Eulachons in the Fraser River and elsewhere. Prior to the 1990s there was a relatively small amount of research directed at Eulachon, with few scientific reports. To better ascertain the state of Eulachons in other parts of the BC coast, DFO, working with the BC Forestry Ministry, started an informal series of meetings called the 'Eulachon Research Council'.

During the period from 1995-2007, many meetings were held in various parts of the BC coast: Kitamaat Village, Terrace, Prince Rupert, Bella Coola and Vancouver. Summaries of presentations at these meetings, and similar meetings, some of which were sponsored by First Nations, were prepared and broadly circulated (see for example references to the Eulachon Research Council 1998, 2000). In many of the recent scientific reports on Eulachon, there is reference to the information provided by these meetings. A key component of these meetings was the participation by representatives of First Nations. In all geographic locations and in all subject areas, their input was fundamental. Therefore much of the information we presently have about Eulachon was first provided by First Nations. Even the research projects that expanded our knowledge base about Eulachon, such as the first Status report (Hay and McCarter 2000) or the first definitive genetics papers (McLean *et al.* 1999, McLean and Taylor 2001, Beacham *et al.* 2005) relied on significant First Nations participation for the collection of samples. The first egg and larval surveys used in stock assessments of the Fraser River (Hay *et al.* 2005) were designed in accordance with information provided by First Nations communities along the lower Fraser River.

In this report it was impractical to distinguish between information and knowledge originating from First Nations versus other sources. There is far too much in this report that is derived, directly or indirectly, from First Nation sources. Therefore we chose to not include a separate section on Aboriginal Technical Knowledge (ATK) because such a section would have made this report unnecessarily disjointed. The ATK component in this report is fundamental. The absence of a distinct ATK section is not an oversight – rather it is an acknowledgement that First Nations input is pervasive, fundamental and substantial.

This report was written before the COSEWIC ATK Subcommittee protocols were established and the ATK presented here was collected through a separate process.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2011)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada
Canadian Wildlife Service

Environnement Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Eulachon
Thaleichthys pacificus

Nass / Skeena Rivers population
Central Pacific Coast population
Fraser River population

in Canada

2011

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WILDLIFE SPECIES INFORMATION

Name and classification

The Eulachon (*Thaleichthys pacificus*) is one of 31 species in the Family Osmeridae. They are thought to be closely related to two southern hemisphere families: the Galaxiidae and the Retropinnidae. There are few fossil records for osmerids (McAllister 1963). Osmerids are members of the Order Osmeriformes, which relates them to relatively early forms of modern bony fishes.

The Eulachon is known by a number of common names of which 'Eulachon' is the scientifically recognized common name. However, the common spelling varies and sometimes it is spelled as 'ooligan' or 'oolichan' or 'oolachon', etc. Frequently the letter 'h' is inserted, for 'hooligan' and pronounced with a hard 'h'. This latter pronunciation seems common in Alaska and parts of BC although American biologists often insert a 'y' at the beginning of 'Eulachon' to pronounce it as 'yoolachon' (as in the common pronunciation of 'eulogy').

First Nations have different names for Eulachon but none are similar to the sound or pronunciation of 'Eulachon'. The word Eulachon is supposed to have an origin from 'Chinook' (Hart 1973) the synthetic trading language made up of French, English and various First Nations languages. Hay and McCarter (2000) suggest that the name might have been derived from French, with the first syllable referring to oil (or huile in French) and the last to candle (or chan, short for 'chandelle' in French). Such a derivation would be consistent with one of the common names for Eulachon, 'candle fish'. Byram and Lewis (2001) suggested that the name of the state of Oregon was based on the term 'nooligan' (pronounced as oor-i-gan), that was a First Nations term for grease.

Morphological description

Morphologically, Eulachon resemble small Pacific salmon, having an adipose fin and long anal fin. They are small fish, generally not longer than 20 cm (standard length). Descriptions of meristic variation vary slightly among sources such as Scott and Crossman (1973), Hart (1973) and Mecklenburg *et al.* (2002). In general there are about 10-13 dorsal fin rays, 17-23 anal fin rays, 10-12 pelvic fin rays, 19 caudal rays, 6-8 branchiostegal rays. There are between 17-23 gill rakers, 65-72 vertebrae and 70-78 scales along the lateral line canal. The most distinguishing morphological characteristic is a group of concentric lines or 'striae' on the operculum (Hart 1973) although this feature is not obvious in juveniles (<10 cm).

Spatial population ptructure

A review of all reports on Eulachon distribution shows a potential of 38 different spawning rivers in British Columbia, although this number would be slightly greater if it also included spawning runs in tributaries draining into rivers, such as the Skeena. This count of 38 rivers is based on reports by Hay and McCarter (2000), Moody (2008) and

Pickard and Marmorek (2007). This estimate does not include the upstream portions of the Iskut-Stikine, Taku and Alsek in the northwestern corner of BC that drain into southeast Alaskan waters as indicated by McPhail (2007). It is certain that Eulachon use the downstream sections of these rivers, but the penetration of Eulachon through Alaskan territory into Canadian areas in uncertain, and therefore these rivers are not included in this review.

Figure 1 shows all known Eulachon spawning rivers in Canada corresponding to the list in Table 1, organized approximately from north to south. Table 1 also groups rivers that share common marine or estuarine waters, particularly inlets. Twelve of these rivers have been fished traditionally and have had regular spawning runs, Nass, Skeena, Kitamat, Kildala, Kitlope, Kowesas, Kemano, Bella Coola, Chuckwalla, Kingcome, Klinaklini, and Fraser.

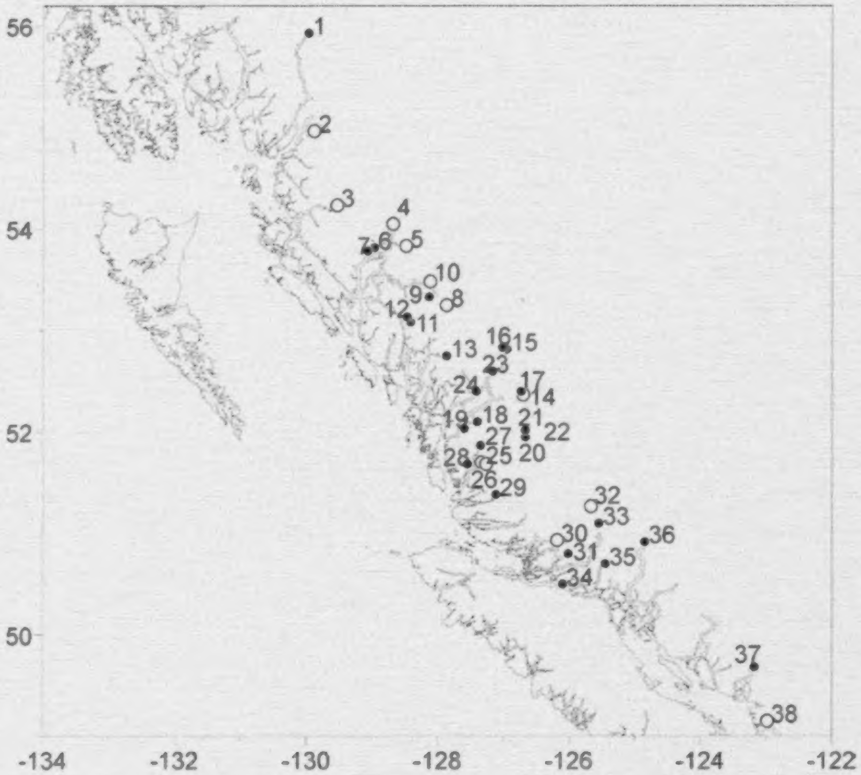

Figure 1. Eulachon spawning rivers in BC. The rivers that are believed to have regular annual spawning are indicated with large open circles. Those that do not have regular spawning runs are shown with small solid circles. The numbers correspond with the list of rivers in Table 1.

Table 1. List and classification of 38 known and probable Eulachon spawning rivers (updated from Hay and McCarter 2000 using information from Moody (2008) and elsewhere). The column 'size' classifies each river as large (L), medium (M), small (S) or very small (V). The column 'Traditional fishing river' is an evaluation of whether the river ever supported First Nations or commercial fisheries. The approximate marine area most closely connected to the river is shown as 'Estuary-Marine areas'. The most probable 'designatable unit' (DU) or population grouping, based on genetics, habitat and the geographic distribution is listed under the column 'DU'. The far-right column comments on the type of data sources available for each river.

	Spawning River	Size	Traditional fishing river	Estuary-Marine areas	DU	Type of information on status
1	Bear	M	No	Portlant Inlet	Nass/Skeena	nil
2	Nass	M	Yes	Portland Inlet	Nass/Skeena	Catch and effort time series, historical, ATK
3	Skeena	L	Yes	Chatham Sound	Nass/Skeena	ATK, occasional assessment work
4	Kitimat	M	yes	Douglas Ch - Kitimat Arm	Central	ATK, catch and effort time series, one year egg-larval SSB assessment
5	Kildala	S	yes	Douglas Ch - Kitimat Arm	Central	ATK – confirmation of low or absent runs
6	Gilttoyees Inlet	V	no	Douglas Ch.	Central	DFO – larval survey
7	Foch Lagoon	V	no	Douglas Ch.	Central	DFO – larval survey
8	Kitlope	M	Yes	Gardner Canal – head	Central	ATK – confirmation of low or absent runs
9	Kowesas	M	uncertain	Gardner Canal - Chief Matthew's Bay	Central	ATK – confirmation of low or absent runs
10	Kemano/ Wahoo	M	yes	Gardner Canal - Kemano Bay	Central	ATK, catch and effort time series, some egg-larval SSB assessment
11	Khutze River	V	no	Princess Royal Ch. - Khutze Inlet	Central	DFO – larval survey
12	Aaltanhash	V	no	Princess Royal Ch. - Aaltanhash Inlet	Central	DFO – larval survey

	Spawning River	Size	Traditional fishing river	Estuary-Marine areas	DU	Type of information on status
13	Kainet or Lard Creek	V	no	Kynoch Inlet - Mathieson Ch.	Central	DFO – larval survey
14	Bella Coola	M	yes	North Bentinck Arm	Central	ATK, DFO catch data, recent egg and larval SSB surveys
15	Kimsquit	M	sometimes	Dean Ch.-	Central	ATK – confirmation of low or absent runs
16	Dean River	M	sometimes	Dean Ch.	Central	ATK – confirmation of low or absent runs
17	Necleetsconay/Paisla Creek	S	no	Dean Ch.	Central	ATK – confirmation of low or absent runs
18	Kwatna	S	no	Dean Ch.	Central	ATK – confirmation of low or absent runs
19	Quatlena	S	no	Dean Ch.	Central	ATK – confirmation of low or absent runs
20	Aseek	S	no	Dean Ch.	Central	ATK – confirmation of low or absent runs
21	Noeick	S	no	South Bentinck Arm	Central	ATK – confirmation of low or absent runs
22	Taleomy	S	no	South Bentinck Arm	Central	ATK – confirmation of low or absent runs
23	Skowquiltz	S	no	Dean Ch. - west side	Central	ATK – confirmation of low or absent runs
24	Cascade Inlet	V	no	Dean Ch.	Central	ATK – confirmation of low or absent runs
25	Chuckwalla/Kilbella	M	yes	Rivers Inlet - Queen Charlotte Strait	Central	ATK – confirmation of low or absent runs, some limited catch data and egg and larval SSB data

	Spawning River	Size	Traditional fishing river	Estuary-Marine areas	DU	Type of information on status
26	Wannock	M	yes	Rivers Inlet - Queen Charlotte Strait	Central	ATK – confirmation of low or absent runs, some limited catch data and egg and larval SSB data
27	Clyak River, Moses Inlet	S	no	Rivers Inlet-Moses Inlet	Central	ATK – confirmation of low or absent runs
28	Hardy Inlet (uncertain source)	?	no	Rivers Inlet	Central	DFO – larval survey
29	Nekite, Smith Inlet	S	uncertain	Smith Inlet	Central	Nil
30	Kingcome	M	yes	Kingcome Inlet	Central	ATK, limited catch data, time series on grease production as proxy index of anundance
31	Kakweiken	S	no	Thompson Sound - Johnstone Strait	Central	DFO – larval survey
32	Klinaklini	M	yes	Knight Inlet	Central	ATK, catch data time series, occasional egg and larval SSB assessment
33	Franklin	S	sometimes	Knight Inlet	Central	ATK, one year (2009) of egg and larval assessment
34	Port Neville	V	no	Johnstone Strait	Central	
35	Stafford/ Apple	V	no	Loughborough Inlet	Central	DFO – larval survey
36	Homathko	M	no	Bute Inlet - Johnstone Strait	Central	ATK, DFO – larval survey
37	Squamish	M	no	Howe Sound-Georgia Strait	Central	No data, limited historical reference to use of river
38	Fraser	L	yes	Georgia Strait	Fraser	ATK, long time series of DFO catch data, effort data for short periods, intensive 15-year egg and larval SSB time series

Within their geographic range Eulachon spawn only in rivers that have pronounced spring runoffs and that drain large snowpacks or glaciers. There are no established populations spawning in rivers draining coastal islands, such as Vancouver Island, or any others in BC. Within rivers the duration of the spawning period may be several weeks. Usually spawning begins in January or February in southern rivers such as the Columbia River, and extends into June in rivers in northern Alaska, but there is unexplained variation within this range. Within southern BC the Fraser River population spawns mainly in April, later than most northern BC populations, such as those in the Nass and Skeena rivers that spawn mainly in March.

Genetic description

Beacham et al. (2005) examined genetic variation of 14 microsatellite loci from approximately 1900 fish from nine spawning sites, located between the Columbia River and Cook Inlet, Alaska. All loci surveyed in Beacham *et al.* (2005) were polymorphic: the number of alleles at each locus ranged from 13-62; expected heterozygosity at a locus ranged from 0.54 -0.95. Expected heterozygosity was similar among all putative populations, ranging from 0.78 to 0.81. Genotypic frequencies at each locus within sampling location and year generally conformed to those expected under Hardy-Weinberg equilibrium, with the possible exceptions of three loci: *Tca19*, *Tca21*, and *Tca22,* where substantially more of the HWE tests were significant than would be expected by chance. More homozygous fish than expected were observed at these loci. Samples from the major river systems in BC accounted for over 50% of the non-HWE distributions of allele frequencies (Skeena River 6 tests significant, Nass River 4 tests, Fraser River 3 tests). This implies that those samples may have contained fish from at least two separate spawning populations (homozygous excess as a result of the Wahlund effect).

Gene diversity analysis of the 14 loci was used to determine the magnitude of annual variation within populations. Only three of the putative BC populations, Nass, Kemano and Bella Coola rivers, had two or more years of sampling. The amount of variation contained within populations averaged 99.6% for the microsatellite loci. Variation among the three putative populations was the largest for Tca4, accounting for 1.8% of total observed variation at the locus ($F=7.62$, df $=2$ and 3, $0.5<P<0.10$). Population differentiation at Tca17 accounted for 1.4% of the observed variation ($F=9.19$, df $=2$ and 3, $0.05<P<0.10$). For the remaining loci, differentiation among sampling years within populations was similar to the level of differentiation among populations.

The overall FST for the 14 microsatellite loci surveyed was 0.0046, with individual loci values ranging from 0.0014 at Tca15 to 0.0212 at Tca11, and with 10 of 14 values significantly greater than zero ($P<0.05$). Virtually all pairwise FST values were significant between the nine putative populations (Table 2). The greatest differentiation was observed between the Columbia River drainage populations and populations north of the Fraser River. Surprisingly, within the Columbia River drainage, reduced but statistically significant differentiation was observed between samples from the Cowlitz River and from the mainstem of the Columbia River, although the samples were collected in different years.

Table 2. Pairwise FST test statistics averaged over 14 micro-satellite loci for Eulachon from 9 river locations (see text and Fig. 2 for explanation of sources). All values were significant ($P<0.05$) except for those in parentheses (from Beacham *et al.* 2005).

	Cowlitz	Fraser	Klinaklini	Bella Coola	Kemano	Skeena	Nass	Twentymile
Columbia	0.0020	0.0022	0.0130	0.0108	0.0083	0.0073	0.0085	0.0068
Cowlitz		0.0016	0.0095	0.0083	0.0066	0.0039	0.0056	0.0048
Fraser			0.0083	0.0062	0.0049	0.0038	0.0051	0.0052
Klinaklini				(0.0014)	(0.0022)	(0.0033)	(0.0037)	0.0091
Bella Coola					0.0019	0.0033	0.0037	0.0071
Kemano						0.0016	0.0028	0.0068
Skeena							0.0035	0.0056
Nass								0.0056

Beacham *et al.* (2005) used Cavalli-Sforza and Edwards' chord distance to estimate the genetic distance among all putative populations. There was some regional structuring: southern populations (Fraser, Columbia, and Cowlitz) clustered together 97% of the time, and central coast populations (Bella Coola, Kitimat, and Kemano) clustered together 88% of the time (Figure 2). The regression of all pairwise FST values on geographic distance was significant (r=0.34, P<0.05) and geographic distance accounted for 11.3% of the observed variation in FST values. The significant correlation between genetic and geographic distances for putative Eulachon populations was consistent with an isolation-by-distance relationship, but clearly factors other than geographic separation also contributed to the observed genetic variation. Beacham *et al.* (2005) also estimated the mixed stock origin of Eulachon taken in three offshore sampling sites – west coast of Vancouver Island, central BC (Queen Charlotte Sound), and northern BC (Chatham Sound). Fish from the Columbia and Fraser Rivers dominated the sample from the west coast Vancouver Island. The sample from central BC had Eulachon from all regions. The sample from northern BC was dominated by Eulachon from the Nass, Skeena, Kemano, and Bella Coola rivers (Table 3).

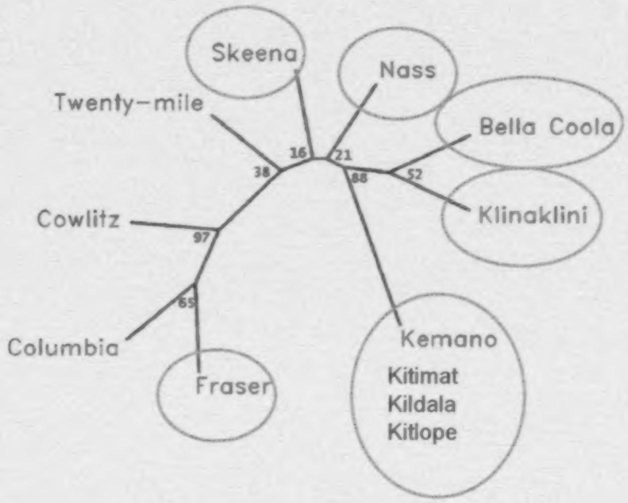

Figure 2. Unrooted neighbour-joining tree chord distance for 9 populations of Eulachon surveyed at 14 microsatellite loci. Bootstrap values at the tree nodes indicate the percentage of 500 trees where populations beyond the node clustered together. The names within red circles show six of the eight putative DUs. The Twenty-mile sample is from a river that drains into Cook Inlet, Alaska. The Cowlitz River is a tributary that drains into the mainstem of the Columbia River (from Beacham *et al.* 2005).

Table 3. Estimated percentage stock composition of Eulachon as bycatch in shrimp trawl surveys near Chatham Sound (CHA), Queen Charlotte Sound (QCS), and off the west coast of Vancouver Island (WCVI) during May 2000 (Beacham *et al.* 2005).

Baseline population	CHA	QCS	WCVI
Columbia	0.6	2.5	15.1
Cowlitz	1.1	22.1	41.5
Fraser	2.1	23.9	37.5
Klinaklini	4.0	1.1	2.3
Bella Coola	12.3	1.1	0.6
Kemano	35.3	21.5	0.3
Skeena	7.3	27.1	0.5
Nass	37.4	0.7	2.3

Table 4. List of three putative designatable units (DUs) showing clusters of rivers within some DUs. Several rivers, such as the Stuart, or other small rivers or streams without a history of spawning or fishing, cannot be classified according to a DU.

Designatable Unit	Eulachon Spawning River(s)
Nass/Skeena	Bear, Nass, Skeena
Central	Kitimat, Kildala, Kitlope, Kowesas, Kemano, Wahoo Giltoyees, Foch Inlet creek, Khutze, Aaltanhash, Kainet or Lard Creek, Bella Coola, Kimsquit, Dean, Kwatna, Quatlena, Aseek, Noeick, Taleomy, Skowquiltz Necleetsconay/Paisla Creek, Chuckwalla/Kilbella Rivers, Wannock River,,Clyak River in Moses Inlet, Nekite, Kingcome, Kakweiken, Klinaklini, Franklin, Port Neville, Stafford/Apple, Homathko, Squamish
Fraser	Fraser River

Flannery *et al.* (2009) corroborate and extend the main findings of Beacham *et al.* (2005). Genetic differentiation of Alaskan Eulachon populations is characterized by broad-scale geographic variation, consistent with an isolation-by-distance hypothesis, but with an absence of the same degree of relatively fine-scale geographic variation as observed in the more southern regions of BC and Washington. Flannery *et al.* (2009) point out that this pattern is not surprising given the probable post-glacial recolonization of Eulachon, from a single refugium in the south, to more northern areas of the eastern Pacific. Specifically, Eulachon in the south have had more time to differentiate than those in the north. Flannery *et al.* (2009), like Beacham *et al.* (2005), conclude that the genetic results support the view that homing to freshwater natal areas may not be precise thus preventing the same degree of fine-scale geographic variation seen in many salmon (*Oncorhynchus*) populations.

Designatable units

The Species at Risk Act recognizes that conservation of biological diversity requires protection for taxonomic entities below the species level (i.e., designatable units or DUs), and gives COSEWIC a mandate to assess those entities when warranted. DUs should be discrete and evolutionarily significant units of the taxonomic species, where "significant" means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion (COSEWIC Operations and Procedures Manual April 2010).

There is a hierarchical range of potential DUs that can be considered for Eulachon. At one extreme, the entire Canadian range may be considered as a DU. However, given that this is an anadromous semelparous species found only in mainland rivers with pronounced spring runoffs, that the run timings in these different rivers are spatially structured, and the available genetic data indicate an isolation-by-distance relationship, a finer geographic DU structure seems more appropriate.

The genetic data indicate that the Fraser River Eulachon are isolated from other Canadian spawning populations. The spawning time of the Fraser population also departs from the normal south-north cline common to many fish populations, with spawning in the Fraser being considerably later in the year than that of rivers further north. The Fraser River, like the Nass and Skeena, has a drainage basin that extends well inland. This suggests that the Fraser River population should be considered a separate DU.

Eulachon south of the Skeena River and north of the Fraser River spawn in rivers with head waters in the Coast Mountain Range. The genetic data from rivers in this area indicate a high degree of separation from rivers to the north and south (Figure 2). These fish do not appear in at-sea samples from the west coast of Vancouver Island. This suggests that fish from these rivers form a second DU, which will be referred to as the Central Pacific Coast DU. For brevity the term Central DU is also used in this report. The names Central Pacific Coast DU and Central DU refer to the same DU.

The Nass and Skeena Rivers, like the Fraser River, have their headwaters deep in the BC interior. There is a high degree of genetic separation between these two rivers and others in Canada (Figure 2). As with fish from the Central DU, these fish do not appear to migrate to the west coast of Vancouver Island while at sea. As will be discussed later, the Nass population appears to be in relatively better condition than other populations in Canada. This suggests that fish in the Nass and Skeena Rivers constitute a third DU, referred to as the Nass/Skeena DU. The Bear River, which is north of the Nass, has been reported to possibly support Eulachon runs (Anon 2006). The Nass and Bear Rivers both enter Chatham Sound through Portland Inlet. Very little is known about Eulachon in the Bear River. In the absence of data, the Bear River is provisionally included in the Nass/Skeena DU.

The allocation of rivers to the three suggested DUs is shown in Figure 3. The suggested geographic boundaries between DUs are as follows. The Nass/Skeena DU is bounded to the north by the Canada/U.S. (Alaska) border and to the south at a point mid-way in Grenville Channel (53°41'6.24"N 129°45'38.98"W) and extending southwest across Banks Island. The Fraser DU is bounded to the south by the Canada/U.S. (Washington State) border and to the north at Point Grey (49°16'4.43"N 123°15'42.66"W). The Central DU lies between the southern border of the Nass/Skeena DU and the northern border of the Fraser DU.

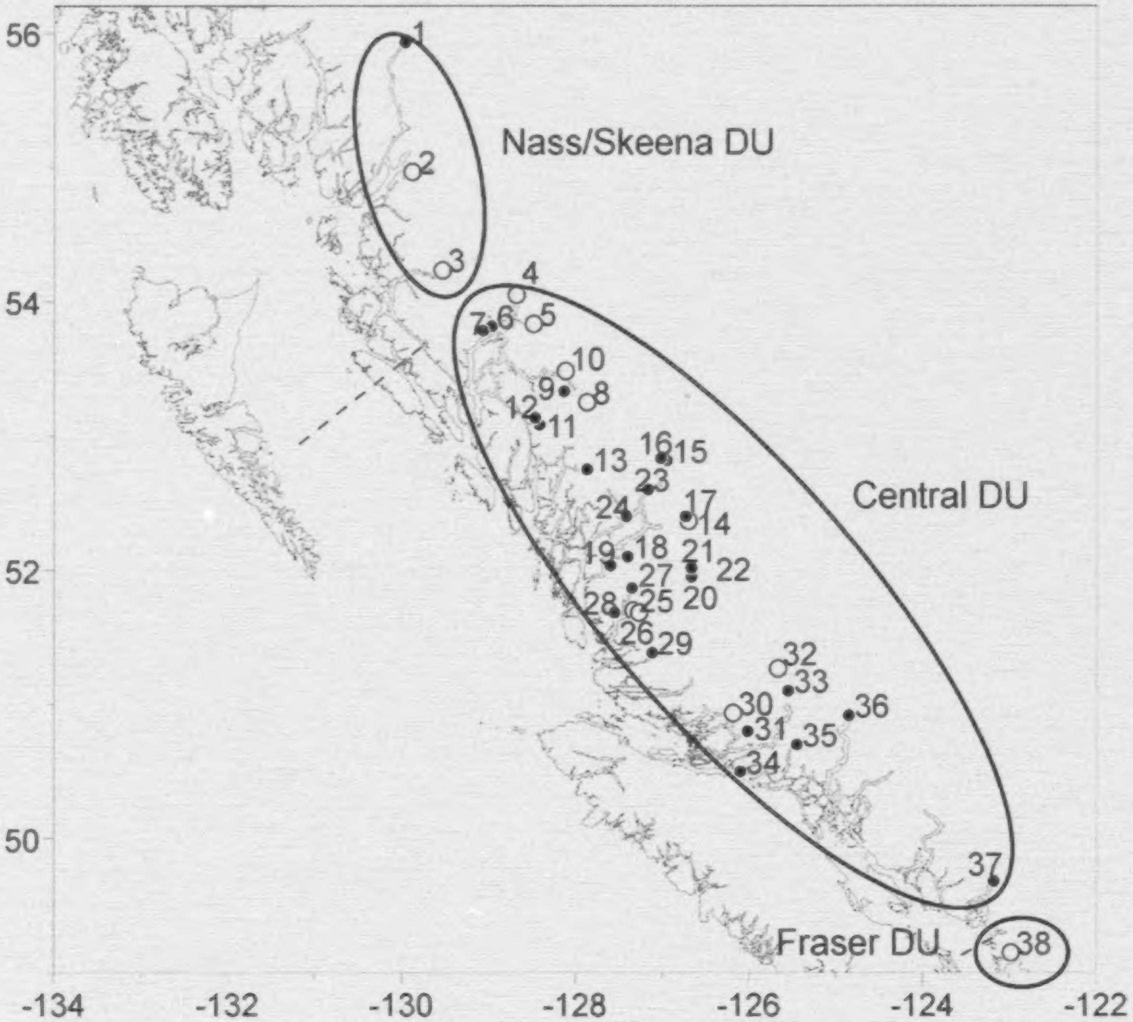
Nass/Skeena DU
Central DU
Fraser DU
56
54
52
50
-134
-132
-130
-128
-126
-124
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Figure 3. Suggested Eulachon designatable units (DUs) in Canada. The ellipses contain rivers in each named DU. The dashed lines are suggested geographic separation points. The numbers correspond with the list of rivers in Table 1. The rivers that are believed to have regular annual spawning are indicated with large open circles. Those that do not have regular spawning runs are shown with small solid circles.

DISTRIBUTION

Global range

Eulachon are found only in the eastern Pacific, from northern California to the eastern Bering Sea (Figure 4). Eulachon are not known in Russian waters (Nikolai Naumenko, Kamchatka Research Institute of Fisheries and Oceanography, Petropavlovsk, Russia pers. comm.). In North America, Eulachon distribution coincides closely with areas known as the coastal temperate rain forest (Simenstad *et al.* 1996) although there may not be any functional linkage.

Most osmerid species are found in the north Pacific and it seems probable that the Pacific is the centre of origin. Only two species occur in the Atlantic and they also occur in some Arctic waters, suggesting that only those smelt species were able to tolerate sub-Arctic conditions and pass through the Arctic to reach Atlantic waters (McAllister 1963). Within the Pacific, the Eulachon, like most other osmerid species has a boreal distribution.

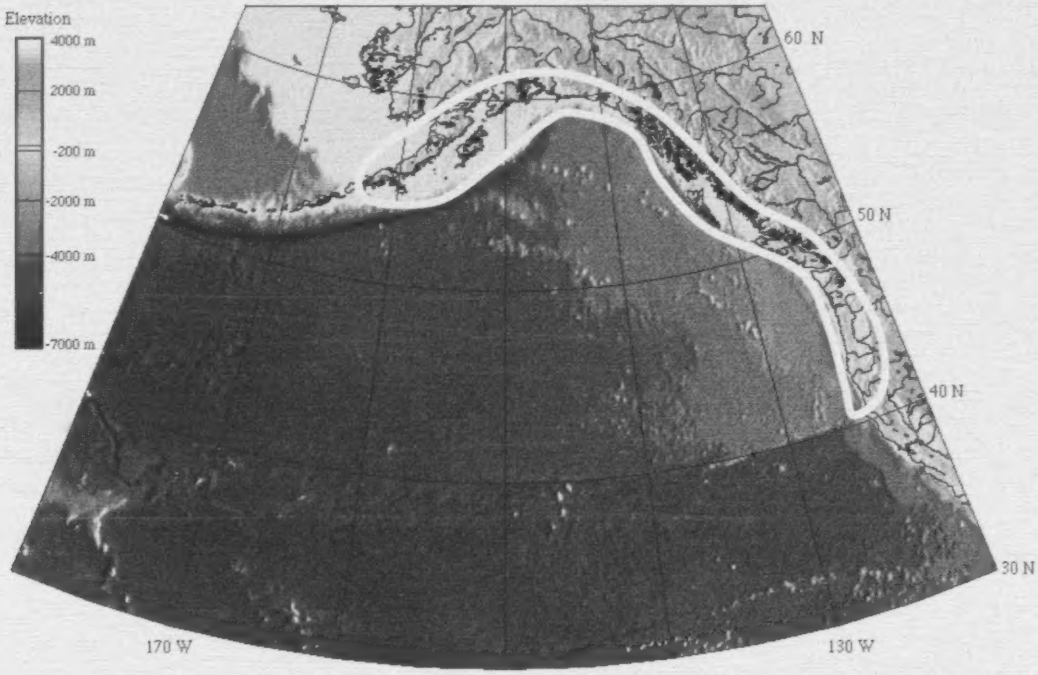


Figure 4. The global distribution of Eulachon in the North Pacific is shown within the white line. Eulachon extend southwards to California and north to the Bering Sea, but the extent of their northern spawning distribution in Alaskan rivers is uncertain.

The most southerly record of Eulachon in offshore waters is reported by Weinberg *et al.* (1994) who described species captured in offshore surveys of the continental U.S. in 1989. Eulachon are listed as occurring from 34° 36' to 49° 35' latitude (Weinberg *et al.* 1994, Table 2, page 29) but the northern edge of the range is uncertain. Eulachon are routinely captured in the southern Bering Sea during NOAA surveys. It is possible that these Bering Sea Eulachon may spawn in several rivers that drain into the southern Bering Sea: the Bear, Sandy or Meshik rivers (Willson *et al.* 2006).

Distribution of spawning Rivers in US waters

Appendix 1 presents a review of distribution in US waters. Approximately 35 rivers in Alaska may support Eulachon (Kitto 2000). Detailed distribution maps are provided by Willson *et al.* (2006). The largest are the Unuk, Stikine, Taku, Mendenhall and Chilkat Rivers in southeastern Alaska, the Situk River near Yakutat, the Copper River near Cordova and the Kenai, Susitna and Twentymile Rivers in Cook Inlet (Bartlett and Dean 1994). Eulachon in the southeastern rivers return as early as April, while those in the central Alaskan rivers, commonly return in May (Bartlett and Dean 1994).

Historically the major Eulachon rivers in California were the Klamath River in Del Norte County and the Mad River and Redwood Creek in Humboldt County (Odemar 1964). There are incidental reports of Eulachon returning to the Smith River; however, these runs were not large or regular (Moyle *et al.* 1995). The southernmost capture of Eulachon occurred off the coast of California in April 1964, five miles southwest of Bodega Bay, Sonoma County (Odemar 1964). As a result of these catches, the California Department of Fish and Game revised the southernmost range of Eulachon, to approximately 180 miles south of the Mad River. Six fish were also captured near the mouth of the Russian River in April 1963 but no sustained runs have been reported returning to this river or any other river south of the Mad River (Odemar 1964).

Canadian distribution

The distribution of Eulachon within Canada is limited to Pacific marine waters and the lower reaches of rivers draining into the Pacific. Eulachon are not found in marine waters of the Arctic or Atlantic or any freshwater drainages draining into the Arctic or Atlantic Oceans.

Eulachon spawning in Canada is restricted to continental rivers with spring freshets that drain large snow packs and glaciers. Most Eulachon rivers have their headwaters in the Coast Mountain Range. However, the largest runs spawn in the lower reaches and tributaries of the Nass, Skeena, and Fraser rivers, which drain the interior of British Columbia. There are no Eulachon rivers on Vancouver Island or the Queen Charlotte Islands.

The 3-year period between hatching and spawning appears to be spent mainly in near-benthic habitats in open marine waters. Based on analyses of Eulachon distribution as bycatch in shrimp trawls, and as incidental capture during research trawls, Eulachon appear to live near the ocean bottom in waters of moderate depth (50-200 m) (Hay *et al.* 1998, 1999). They are rarely captured in Georgia Strait as adults, and the few instances of capture appear to be related to their spawning migration to rivers.

The distribution of juvenile and pre-spawning Eulachon in the marine waters off BC (Figure 5) was compiled from a review of all incidental catches of Eulachon in research surveys conducting 30-min tows with mid-water trawl nets. The sources of all the data are listed in Appendix 2. Analyses of incidental catches of Eulachon show that most were taken between the 50-200m depth contours or along the edges of offshore banks. Most Eulachon were captured in mid-water trawl nets fishing close to the sea floor and targeting Pacific Herring. Juvenile Eulachon were also captured in shallower, inshore areas (e.g., Barkley Sound and Quatsino Inlet). There were no Eulachon in the central region of Georgia Strait. Eulachon captured in Juan de Fuca Strait (Figure 5) were trawled during fall/winter Herring hydro-acoustic surveys in the 1970s when large schools of mid-water fish (e.g., Herring, dogfish, hake and Eulachon) were highly mobile and migrating in the Strait.

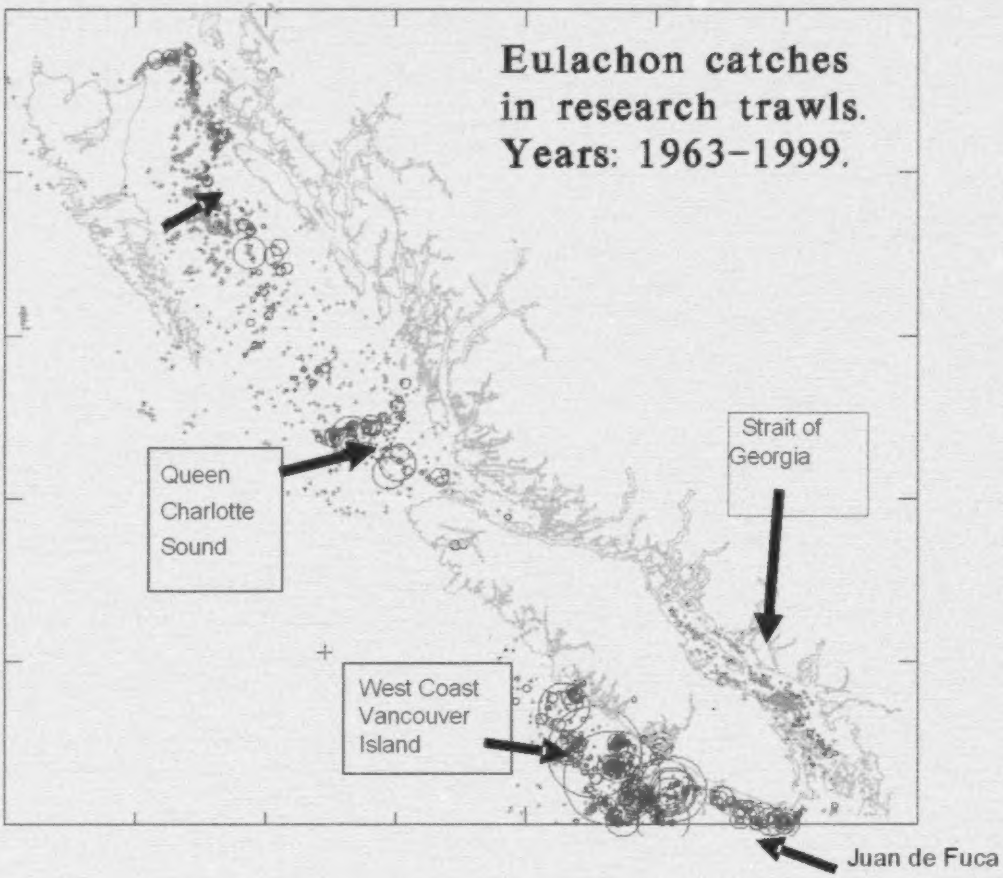


Figure 5. The distributions of Eulachon captured off the coast of British Columbia as depicted by a series of 30-minute, research mid-water trawl tows between 1963 and 1999 (See Appendix 2 for data sources). Blue circles indicate catch locations and the areas of circles are proportional to the catch weight. The largest circle represents a catch of 848 kg. Red crosses indicate trawl tows where no Eulachon were captured. Numerous exploratory trawl tows from other research cruises where no (or negligible) Eulachon were captured are not plotted on the map. Eulachon shown on the map in Juan de Fuca Strait were trawled during fall/winter Herring hydro-acoustic surveys in the 1970s. This figure also is available online: http://www.pac.dfo-mpo.gc.ca/sci/Herring/herspawn/pages/ocean1_e.htm (accessed March 2, 2010).

The origin of Eulachon caught offshore is described in Beacham *et al.* (2005). Their genetic analyses indicate that most Eulachon taken off the west coast of Vancouver Island are from the Columbia and Fraser rivers, with some from other rivers. Eulachon captured in Queen Charlotte Sound (off the central coast of British Columbia) are primarily from adjacent spawning rivers. Those caught in Chatham Sound (off the northern coast of British Columbia) came primarily from the Nass, Skeena, Kemano, and Bella Coola rivers (Table 3).

HABITAT

Eulachon are anadromous, spawning in the lower reaches of rivers. After hatching, the small pelagic larvae drift downstream to the sea where they spend approximately 3 years before returning to fresh water to spawn. Although they spawn in fresh water rivers and streams, Eulachon are mainly a marine fish, spending more than 95% of their lives in marine waters (Hay and McCarter 2000).

Eulachon live in relatively restricted depth zones in the marine environment, mainly between 50-200 m. Their ecological niche is uncertain but they are most often captured by nets targeting shrimp close to the bottom. However, Eulachon seem to occupy depth strata slightly lower in the water column than those preferred by shrimp.

Eulachon spawning rivers vary in size and physical characteristics. Some are large or turbid, with high sediment loads; others are small and clear. The high sediment loads are not necessarily unnatural, and occur in relatively undisturbed rivers in Alaska, such as the Twentymile River, draining into Cook Inlet (E. Kitto, Eulachon Research Council Minutes 2000). In contrast other Eulachon spawning rivers, like the Kemano, are clear. However, one factor is common to nearly all rivers. Virtually all have spring freshets, which are characteristic of rivers draining large snow packs or glaciers (Hay and McCarter 2000). Perhaps, for this reason, there is no sustained Eulachon spawning in rivers draining coastal islands that do not have substantial glaciers (e.g., Haida Gwaii and Vancouver Island). Some Eulachon runs may occur on Kodiak Island in the Kalsin River and Pillar Creek (Willson *et al.* 2006, citing Blackburn *et al.* 1981) but there also are some glaciers on Kodiak Island.

Both Ricker *et al.* (1954) and Smith and Saalfeld (1955) attempted to relate the timing of spawning to ambient water temperature, but the results were equivocal. Moody (2008) examined temporal changes in spawning distribution in the Bella Coola River where the mean spawning has shifted earlier in recent years, from about day of the year (DOY) 100-110 in the 1950s to about DOY 85-95 in the last decade (Figure 6a). Hay (unpublished analysis shown in Appendix 3, Tables 1-3) compared CPUE of spawning runs in the Fraser River, estimated from data compiled in the 1940s and 1950s (Ricker *et al.* 1954) with more recent CPUE estimates made from 1995-2005 (Figure 6b). The comparison shows that mean spawning times changed from a range of about DOY 110-130 during 1941-1953 to about DOY 100-120 between the years 1995-2005. When the data are aggregated over years and compared between the two periods it appears that the duration of the fishery was longer in the 1941-1953 period, with many large catches occurring in May. In contrast, the recent CPUE data indicate a run starting somewhat earlier and of shorter duration.

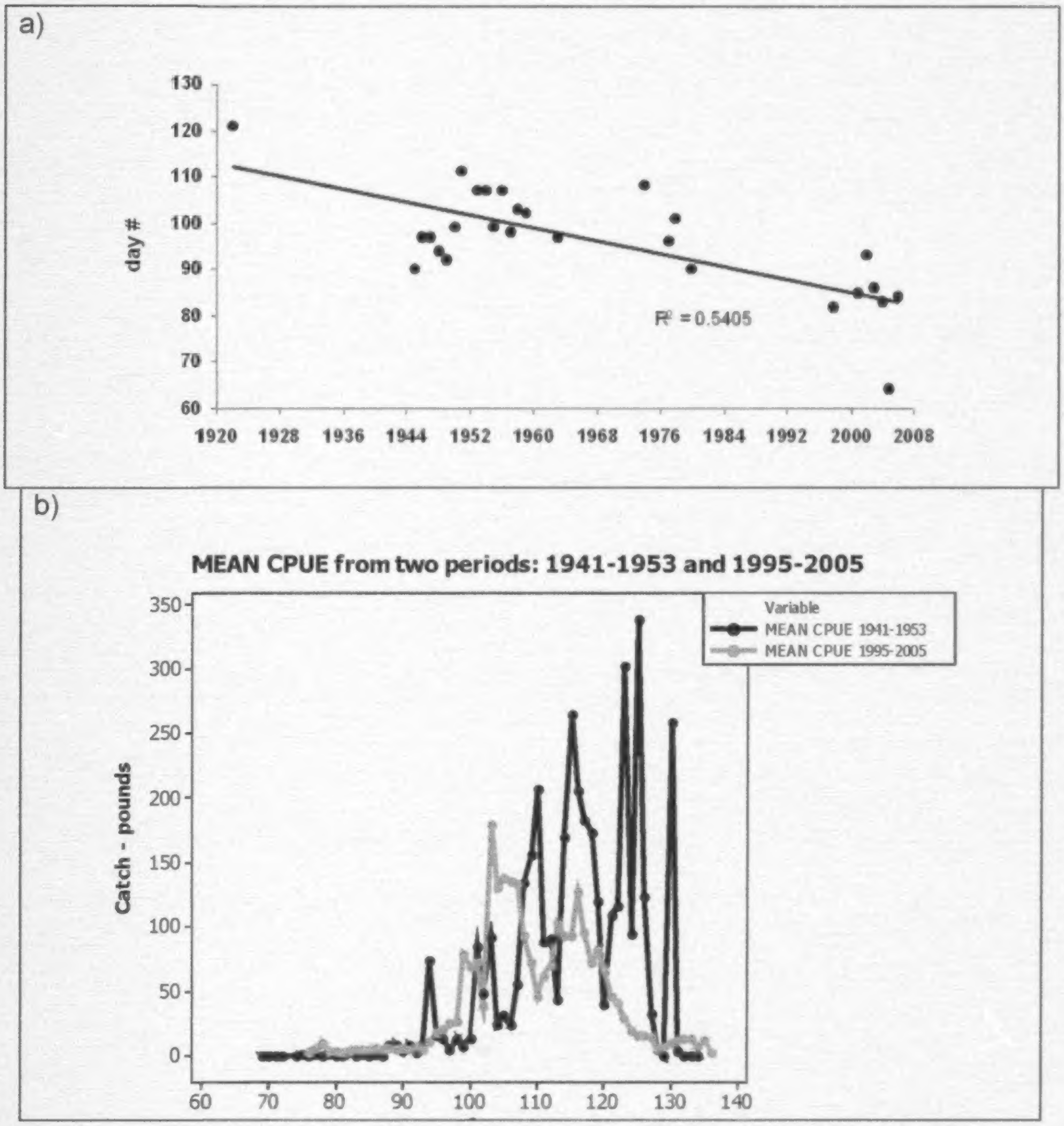


Figure 6. (a) Change in mean spawning dates in the Bella Coola River (from Moody (2008)) and (b) changes in CPUE by day of year (calculated weekly) in the Fraser River between two periods: 1941-1953 and 1995-2004 (Unpublished data, described in Appendix 3).

Eulachon may not be penetrating as far upstream to spawn as they once did in major systems. This is reported on the Skeena River (Don Roberts, Skeena Eulachon fisher pers. comm.), the Bella Coola (Moody 2008) and the Fraser River (Hay *et al.* 2002; Pickard and Marmorek 2007).

Relatively few measures are taken specifically to protect Eulachon habitat, although Eulachon benefit from the generic regulations that apply to all areas and fish species, such as restrictions on industrial pollution and stream management regulations.

BIOLOGY

Life cycle and reproduction

The egg stage

Eulachon eggs are small (<1.0mm diameter) and mildly adhesive. An outer membrane serves as a sticky 'stalk' that anchors the egg. Single eggs or clumps of eggs stick to grains of sand or other debris that appear to 'anchor' eggs to the bottom. The duration of incubation depends on temperature (Smith and Saalfeld 1955); at ambient temperatures of 4-5 ºC (perhaps typical of northern BC rivers), hatching occurs in about 4 weeks. Eggs in the Columbia River hatched over a period of 21-25 days when incubated at temperatures of approximately 8 °C in experimental conditions (Parente and Snyder 1970). Spawning occurs in fresh water but not far above the upper extent of seawater, although in the Fraser or Columbia, this could be 50-100 km upstream.

The larval stage

Eulachon larvae are 4-8 mm in length, elongated with a distinct yolk sac and oil globule, and have the single mid-ventral row of melanophores below the gut characteristic of osmerids (Parente and Snyder 1970, Hearne 1984). In rivers, newly hatched larvae are flushed to sea rapidly, probably within minutes in some smaller rivers and streams. Once in the sea, Eulachon larvae may be retained in low salinity, surface waters in estuaries for several weeks or longer.

Hay and McCarter (1997) report that the distributions of larval Eulachon from closely adjacent rivers overlap. In 1996 and 1997, surveys for Eulachon larvae were conducted in marine waters adjacent to Eulachon spawning rivers, from Georgia Strait to the Douglas Channel. Surveys conducted early in the season showed that larvae were distributed close to known Eulachon spawning rivers whereas surveys conducted late in the season showed that Eulachon larvae were widely distributed along the entire lengths of inlets (Figure 7). Larval samples collected at the heads of inlets, adjacent to known Eulachon spawning rivers, consisted primarily of small, newly hatched larvae. Mean size generally increased in a seaward direction away from Eulachon spawning rivers. A wide range of larval sizes occurred at some sampling stations along Gardner Canal, which suggests mixing of small, newly hatched larvae from the nearby Kemano or Kowesas rivers with much larger larvae, from the more distant Kitlope River at the head of Gardner Canal. Larval mixing was also apparent between Eulachon originating in the Kimsquit and Bella Coola rivers, and between several Eulachon spawning rivers in the Johnstone Strait Region.

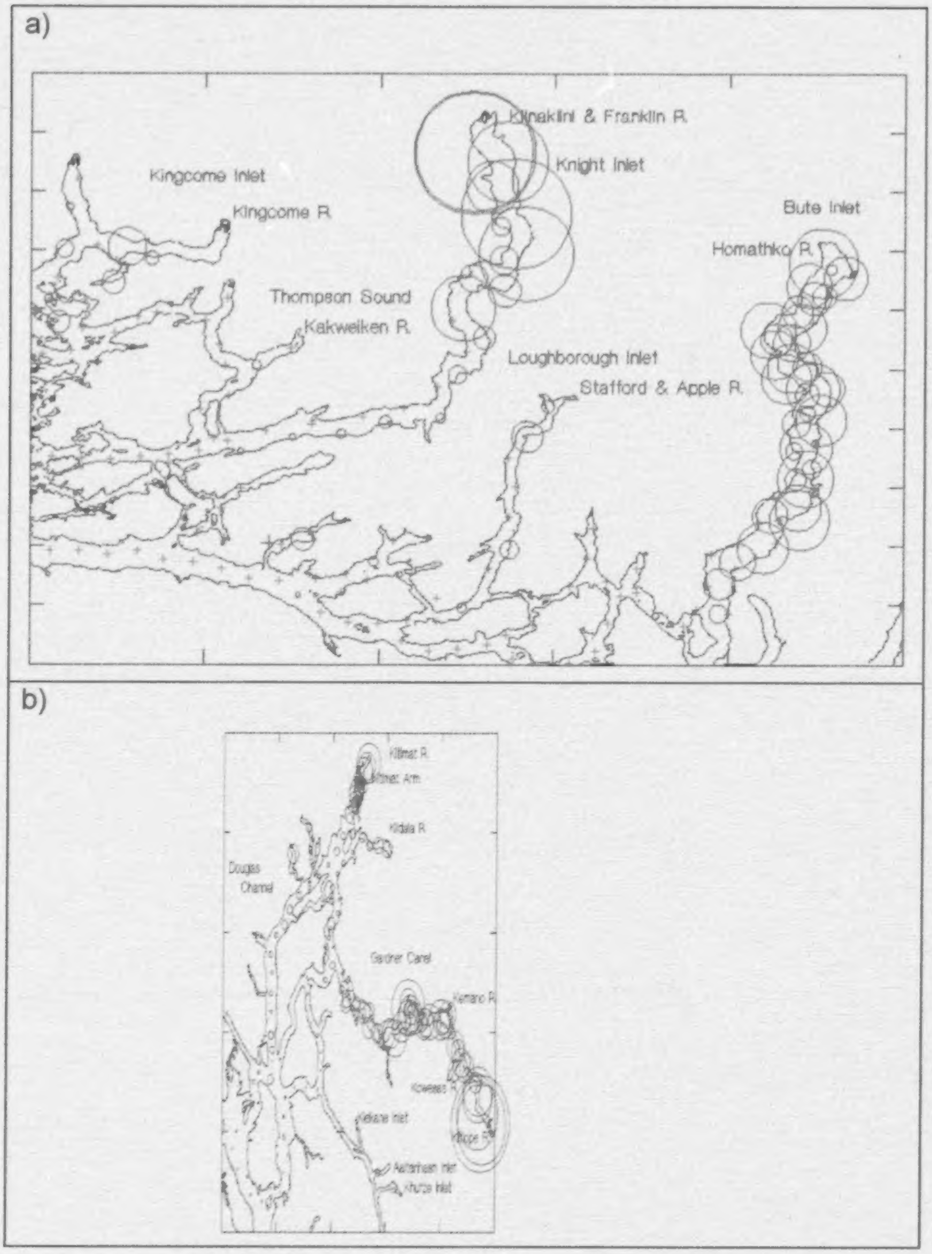

a)
Klinaklini & Franklin R.
Knight Inlet
Kingcome Inlet
Kingcome R.
Bute Inlet
Homathko R.
Thompson Sound
Kakweiken R.
Loughborough Inlet
Stafford & Apple R.
b)
Kitimat R.
Kitimat Arm
Kildala R.
Douglas Channel
Gardner Canal
Kemano R.
Kowesas R.
Kitlope R.
Aaltanhash Inlet
Khutze Inlet

Figure 7. Larval Eulachon density map of (a) Johnstone Strait Region during April 25 – May 5, 1994 showing larval Eulachon distribution in Knight, Loughborough and Bute Inlets. The circle sizes are proportional to larval abundance with a maximum density of 21.3 larvae m^{-3}; (b) Douglas Channel Region during May 27 – June 7, 1996 (maximum density = 32.2 larvae m^{-3}). In both figures, a red cross indicates a station where no Eulachon larvae were captured.

Ichthyoplankton surveys conducted several months following spawning have captured Eulachon larvae in more open ocean areas. One hundred and twenty-eight Eulachon larvae, 12-34 mm in size, were captured late in July and early August at 31 sampling stations located in the centre of Chatham Sound and west of Porcher Island (McCarter *et al.* 1986). No larval Eulachon were captured during similar ichthyoplankton surveys conducted in May of 1985 or 1986 in nearshore areas around Moresby or Porcher Island (Hay and McCarter 1997).

The larval rearing environment in BC's deep, cold and remote inlets seems to be dominated more by physical factors than biological factors. The inlets and deep fjords surveyed are known to be relatively low in overall productivity as compared to the rich, productive offshore banks and adjacent nearshore areas exposed to the open ocean. Therefore, it is likely that some protection from predators is afforded in these inlets while Eulachon larvae absorb their yolk sacs and gradually acquire the characteristics necessary to survive in open ocean environments. Further, the confinement of Eulachon larvae to the upper layers of relatively low saline water (resulting from estuarine circulation) would eliminate most stenohaline predators (i.e., most marine fish and invertebrate predators). As a consequence, small spawning runs of Eulachon may be more sensitive to ocean climate changes particularly those that impact the freshwater discharge than, for instance, large spawning runs of Herring that deposit vast numbers of progeny usually near the centrer of highly productive areas.

The juvenile stage: ages 8 weeks - 12 months

The distribution and ecology of the juvenile stage, when fish are too large to be collected in ichthyoplankton gear, and too small to be retained in fishing nets, is poorly known. The meager information available is from a few data reports on experimental 'two-boat trawl' surveys, mainly from Georgia Strait, and summarized by Barraclough (1964). This report is interesting because Barraclough describes Eulachon as occurring in Georgia Strait, but they are not captured there by commercial shrimp gear (Hay *et al.* 1998, 1999).

The distribution of juveniles is poorly understood, but it seems that individuals disperse to open, marine waters within their first year of life and perhaps within the first few months, because some (which may have been classified either as large larvae, or small juveniles) were taken in plankton nets off Porcher Island in July (McCarter and Hay 1999).

The oceanic, sub-adult and adult stages

Size distributions (Figure 8) during the oceanic phase are known from incidental capture in various research cruises conducted over many years. They are also known from analyses of bycatch in shrimp trawl gear (Hay *et al.* 1997, 1998 and 1999), but these data are confined to limited areas of the coast where shrimp fisheries occur. The size distribution is distinctly bi-modal suggesting two age classes, likely ages 1 and 2 years.

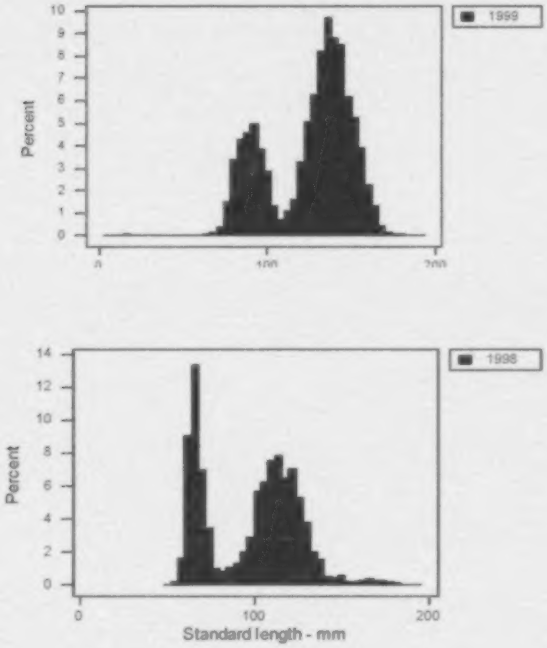


Figure 8. Offshore Eulachon size modes: indications of age. The size modes of Eulachon in May 1998 and 1999, as determined from research surveys of shrimp on the lower west coast of Vancouver Island. There are two distinct modes, which correspond to ages of approximately 1 and 2 years.

From the analyses of incidental catch rates reported from cruise reports seasonal variation in Eulachon catch rates (kg/hour) was observed, with most incidental capture taken in the summer months. Eulachon are found in depths ranging from <10 to 500 m but most are taken in the depth range of approximately 50-200 m. Although the data indicates that in some instances Eulachon may have been captured at depths of nearly 500 m, this is not certain because Eulachon may have been entrained into the nets, either on deployment (descent) or recovery (ascent). In other instances, Eulachon were taken in very shallow water (<10 m). It is not clear if there is a change in size or age composition of Eulachon with depth.

The 'pre-spawning phase' is defined as the period between the end of the summer prior to spawning (when most Eulachon are approximately 2.5 years old) and their arrival at their spawning river, when they are nearly 3 years old. Gonadogenesis occurs during this time. Prior to entering the river, and like salmon, they probably hold in brackish water as they make the physiological changes that allow them to survive in fresh water. Eulachon are semelparous. Somatic tissues are sacrificed for the benefit of gonads, and it appears that females (and perhaps males) resorb minerals from scales and some teeth (Hart and McHugh 1944).

The pre-spawning stage is a period when Eulachon become conspicuous to predators, usually at river mouths. It is also the stage when Eulachon are taken in traditional fisheries. Traditional knowledge is particularly rich on aspects of the spawning biology of Eulachon including factors such as the tidal and river flow conditions that are most suitable for Eulachon. In many rivers, the precise within-river migration route is known, as well as the typical timing

The spawning stage

The duration of the spawning act is not known precisely, but it is likely to last at least hours, and may last for a day or more. Spawning appears to occur mainly at night and involves groups of fish. In contrast to some marine fish such as Herring, Eulachon must closely synchronize the timing of spawning between sexes because the duration of the viability of sperm in freshwater is short, perhaps only minutes.

The post-spawning stage

Eulachon are semelparous so post-spawning mortality often is conspicuous. Mr. Mel Bailey (Katzie FN) describes the banks of the Fraser River as being 'white' with the carcasses of spent Eulachon. Spent carcasses have also been observed to accumulate in the Kemano River estuary, and may do so in other rivers, too. Thus, the post-spawning stage may provide important sources of nutrition for many scavenger species, particularly sturgeon in the Fraser River (Eulachon Research Council Minutes 1998 and 2000). Dead carcasses also could result in a short but substantial inoculation of nutrients to some inlets, and perhaps to Georgia Strait (Hay 1998).

Age of sexual maturation and generation time

The age of Eulachon has been difficult to validate. Most recent age determinations are based on otoliths, but ages determined from otoliths may not be reliable. Ricker *et al.* (1954) compared scales and otoliths from Fraser River fish and found that neither structure provided clear indications of age, and that age estimates from otoliths were typically higher by 1-2 years than those from scales. Clarke *et al.* (2007) have suggested that whole Eulachon otoliths possess numerous dark bands or 'psuedo annuli' which make identifying the specific increments difficult and thus may be wrongly interpreted. Using an alternative method based on seasonal oscillation of Ba:Ca concentrations in Eulachon otoliths, Clarke *et al.* (2007) estimated the age of Eulachon maturity in five rivers and found that the more southerly populations spawned at an earlier age. Eulachon from the Columbia River were estimated to spawn at age 2 years whereas Eulachon from three BC rivers (Fraser, Kemano and Skeena) spawned at age 3 years; Eulachon from the Copper River, Alaska, spawned at age 4 years.

Age may also be estimated by analyses of size distribution from offshore samples. Samples from annual shrimp research surveys conducted in May show 2 distinct size modes (Figure 8) that correspond to ages 1 and 2 (i.e., 12 and 24 months). A few individuals are smaller (age 0+, or a few months of age) and some distinctly larger, corresponding to ages 3 (~36 months). The Eulachon size distribution in rivers spans the largest of sizes found in the sea (Figure 9).

Figure 9. The relationship between the lengths of Eulachon in the sea and Eulachon spawning in rivers. The size frequencies represent the aggregated samples from offshore areas and rivers. The Eulachon spawning in rivers are slightly larger than the largest size modes seen in the sea (taken from Fig. 9 in Hay and McCarter 2000).

Eulachon are semelparous. The best evidence for death after spawning is from teeth. Eulachon spawning in rivers have few teeth, as noted by Hart and McHugh (1944) and many others, probably because the calcium and other minerals have been resorbed prior to spawning, presumably for egg production. The resorption does not seem to be uniform among all bones in the jaw, with few Eulachon retaining some teeth. In contrast, all Eulachon captured in offshore marine waters have large pronounced teeth (D. Hay, pers. Comm.). This observation, combined with the observation that the largest Eulachon are found in rivers, indicates that they do not return to the sea after spawning.

In summary, Eulachon are semelparous and spawn at age 3 years in Canadian rivers. Thus, for the purposes of this report, the generation time is considered to be 3 years.

Fecundity

Fecundity increases with fish length, but the relationship is quite variable, with some small Eulachon having high fecundities and vice versa. Hay and McCarter (2000) describe the relationship between fecundity and length (estimated for the Fraser River only). In general, for most spawning Eulachon, the total fecundity is about 20,000-40,000 eggs.

Predation

Eulachon are an important prey species for marine and freshwater fishes, mammals and birds as they provide a large amount of energy rich food during the spring when food supplies are low. Predation may be particularly intense just prior to spawning when pre-spawning Eulachon concentrate in the lower reaches of rivers. The Nuxalk people of Bella Coola and the Wuikinuxv people of Rivers Inlet both identified the beginning of their Eulachon runs with the arrival of seagulls (*Larus occidentalis*), Bald Eagles (*Haliaeetus leucocephalus*), Harbour Seals (*Phoca vitulina*) and Steller Sea Lions (*Eumetopias jubatus*) (Winbourne and Dow 2002). Collison (1916) witnessed Eulachon being followed into the mouth of the Nass River BC, by "hundreds of seals, porpoises (*Phocoena phocoena)*, sea lions, and Fin Whales (*Balaenoptera physalus*), feasting both on the olachans and upon one another." In 1997, the area-wide bird and mammal tallies for Berners Bay, Southeastern Alaska, during Eulachon runs to the Berners, Lace and Antler Rivers, were 36,500 avian predators, including 536 Bald Eagles, and 422 marine mammals (Steller Sea Lions and Harbor Seals) (Marston *et al.* 2002). Seals and sea lions occur above New Westminster in the Fraser River during the Eulachon spawning period (Hay personal observation). Also, Morton (2000) suggests that the Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*) was feeding on Eulachon in Knight Inlet. However, at other times of the year mammal predation may be lower, particularly as Eulachon occupy relatively deep waters. For instance, Olesiuk *et al.* (1990) describe the feeding of Harbour Seals in Georgia Strait but the incidence of Eulachon is very low relative to other species such as Pacific Herring or Pacific Hake (*Merluccius productus)*. However, Georgia Strait may not be a representative location, as few Eulachon appear to inhabit the Strait, except for the Fraser River spawning migrations. Olesiuk *et al.* (1990) make brief mention of diets in other locations in BC, but the prey is not identified explicitly as 'Eulachon', only as 'smelt'. Even then, the frequency is low.

Eulachon are prey for many marine fish including Pacific Hake (Outram and Haegele 1972), Dogfish (*Squalus acanthias*) (Jones and Green 1977), and Pacific Cod (*Gadus macrocephalus)* (Westrheim and Harling 1983). Outram and Haegele (1972) found that about 5% of the Pacific Hake examined over a 10-day period in 1970 off the lower west coast of Vancouver Island contained Eulachon. The potential significance of this is that Pacific Hake biomass sometimes becomes very high. Although Pacific Hake tend to eat mainly euphausiids, even modest predation by this abundant predator on a relatively scarce prey species like Eulachon, may have a substantial impact on Eulachon. Beamish and MacFarlane (1999) described a recent northward movement of Pacific Hake, as they have expanded to waters of southeastern Alaska. As Pacific Hake move into previously unoccupied habitats (at least within the last century) their substantial predatory biomass might have resulted in local depletions of Eulachon.

Interspecific Interactions

Cursory analyses of Eulachon stomachs from offshore waters indicates they mainly consume a particular euphausiid species (*Thysanoessa spinifera*). Eulachon in the sea have substantial teeth in several different jawbones as well as a relatively low gill raker count (Hart 1973). This indicates that Eulachon are mainly particulate feeders and require teeth to grab and hold their prey.

Physiology

The scientific name for the genus of Eulachon (*Thaleichthys*) is derived from Greek, meaning 'rich fish'. This richness is in the form of very high oil content, which was the basis for the processing and extraction of Eulachon 'grease' by First Nations. This high oil content has been recently confirmed in a comparative study of forage fish in Alaska and the Bering Sea (Payne *et al.* 1999) that found that Eulachon have an oil content of about 20%. This was the highest of all species examined and about 4-5 times greater than most other species of comparable size. The raw fish oil content has also been measured at 11.21% (Daughters 1918), 16.7% (Kuhnlein *et al.* 1996), and between 15.0 and 25.3% (Iverson *et al.* 2002). The biological reason for this exceptionally high oil content is unknown.

Eulachon are anadromous and this requires two periods of osmotic adjustment: the first as an egg or larva, moving from freshwater spawning areas to estuarine and marine habitats; and the second as the period before spawning, when Eulachon enter lower salinity water and probably accommodate physiologically for a short period (days or weeks) before moving upstream.

Adaptability

Over their geographic range Eulachon encounter significantly different spawning conditions. Temperatures in the Fraser River in April and May when spawning occurs can vary between 5 and 10 °C whereas the temperature in the Nass river during spawning time in March may be close to 0 °C if ice is present. It is not clear if Eulachon from one system could tolerate or spawn successfully in the conditions that would be encountered in another area. Eulachon larvae are euryhaline, and when moving through estuaries probably encounter different salinities ranging from virtually fresh water (0 ppt) to full sea water (~31 ppt). Eulachon have no swim bladder so they are able to change depth strata without constraint. Eulachon are not resilient to handling. They lose scales easily and invariably are killed in trawl nets prior to being landed on deck.

POPULATION SIZES AND TRENDS

Search effort

Eulachon abundance and trends have been estimated using fishery data from large rivers (Ricker *et al.* 1954, Langer *et al.* 1977, Hay *et al.* 1997), egg and larvae surveys from spawning rivers (McCarter and Hay, 2003; Hay *et al.* 2002; Moody 2009), larval surveys from estuaries (McCarter and Hay 1999), and swept volume estimates from offshore trawl surveys for shrimp (Hay *et al.* 1997). In addition, historical and ATK information has been described where available.

River assessments - CPUE Indices

Typical analyses of catch and fishing effort data have not been done for Eulachon in the past. However, reliable catch and effort data do exist for several rivers, and trends in catch per unit effort are presented here as indices of abundance. It must be remembered that changes in CPUE only reflect changes in abundance if catchability remains unchanged (or a lack of change in CPUE only reflects a lack in change in abundance if catchability remains unchanged). Samples have been collected systematically with gillnets in the Kitamat River (Beak Consultants 1998). There is a systematic record of catch data for the Nass River (G. Barner, Eulachon Research Council Minutes 2000) and Kitamat River.

River assessments - direct observations

Assessments have also been made based on direct observations and estimates of the dimensions of pre-spawning Eulachon schools in the Kemano River (Triton 1991). This was done by aerial surveys from helicopters and, after adjusting for differences in structure and density of schools, resulted in an estimate of 3.2 million spawners (~150 tonnes time and average weight of 47 gm per spawner). Obviously this method requires relatively clear water and logistical support. Even when directly observed, the estimates could be coarse, although with experience and corroborative information, this method may have application to a few other non-turbid rivers. However, as a method for broader application, this approach has limited potential in most rivers. Another approach is a direct estimate of the numbers of deposited eggs, followed by back-calculation of the numbers of spawners required to deposit the eggs. Triton (1991) made such an estimate on the Kemano River in 1991 and estimated a total of 1.7 million fish (80 t), about half of the estimate made by visual counting of pre-spawning adults. Both approaches have substantial scope for error.

River assessments - larval surveys

Larval surveys have been used to assess adult Eulachon spawning biomass in the Fraser River (Hay *et al.* 2002), the Bella Coola River (Moody 2009) and the Kitimat River (Pedersen *et al.* 1995). Total egg production was estimated as the product of the mean larval density (numbers per m^3) and the river discharge (m^3 per second). The conversion from larval numbers to spawning biomass uses estimates of 'relative' fecundity. For the Fraser River, this was about 700 eggs per gram of spawning female or about 350 eggs/g (males included) from the spawning populations (i.e., spawning biomass = [mean larval density] x [discharge]/relative fecundity). It should be noted that this formula assumes every ovarian egg produces a fertilized egg and a hatched larva that survives. There is no accounting for egg or larval mortality. If one accounts for mortality, the spawner estimate would be higher. For the Fraser River, the larval survey index is assumed to be proportional to spawning numbers.

A few similar SSB assessments based on egg and larval surveys have been made on other rivers including: a one-year survey on the Nass with an estimate of 1700 t, based on unpublished data from U. Orr and presented in an appendix in McCarter and Hay (1999), one on the Kitimat (Pederson *et al.* 1995), seven years on the Bella Coola River from 2001-2007 (Moody 2009) and a one-year survey on the Klinaklini made by M. Berry (Eulachon Research Council Minutes 1998).

Offshore surveys

Estimates of Eulachon biomass are available from shrimp surveys in areas off the west coast of Vancouver Island and Queen Charlotte Sound (http://www-ops2.pac.dfo-po.gc.ca/xnet/content/shellfish/shrimp/Surveys/0902.pdf). (Accessed March, 2 2010) and groundfish surveys in Hecate Strait (Sinclair *et al.* 2007). The apparent coherence of the Columbia River catch data and the offshore biomass index (for all years up to 1996) led Hay *et al.* (1997) to speculate that Eulachon offshore of the west coast of Vancouver Island may have originated from the Columbia River. More recent genetic analysis of these offshore catches indicates that they comprise Eulachon from predominately the Fraser and Columbia Rivers, with most (perhaps two-thirds) originating from the Columbia (Beacham *et al.* 2005 and Table 3).

Abundance trends offshore

Indices of Eulachon abundance in three areas off the west coast of Vancouver Island were relatively low and variable from 1973 – 1993 (Figure 10a). The indices were low from 1994 – 1999 and then increased considerably to peak in all areas in 2003. The indices then declined to levels similar to the 1980s. The time series for Queen Charlotte Sound is shorter, beginning in 1998. However, the pattern is similar to that from the west coast of Vancouver Island with peak abundance in 2001 – 2003 (Figure 10b). The time series for groundfish surveys in Hecate Strait covered 1984 – 2003 (Figure 10c). Eulachon abundance estimates were low from 1984 to 1995, but increased to a maximum value in the last year of the survey in 2003 (Sinclair *et al.* 2007), similar to what was observed in the other (shrimp) surveys.

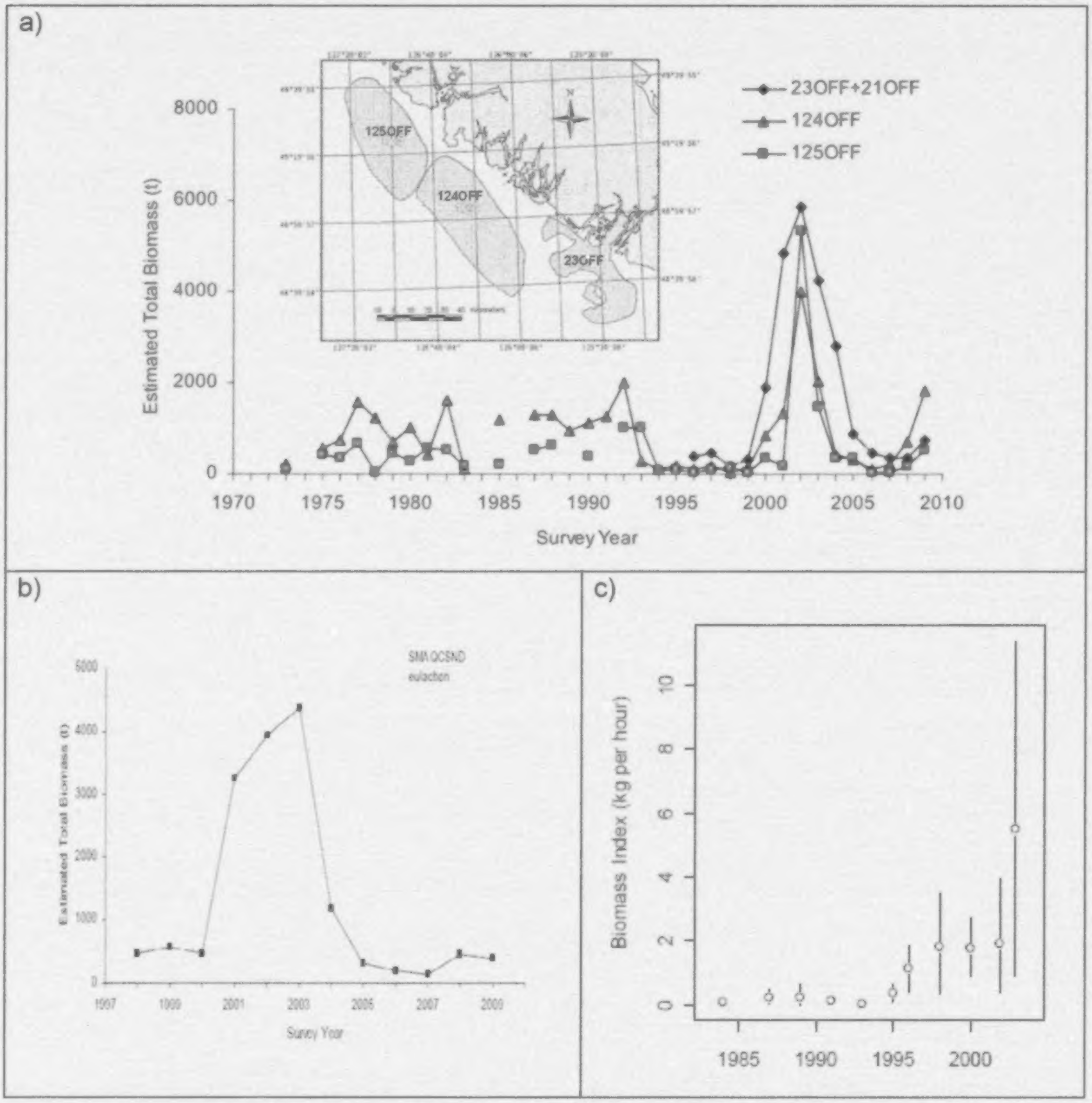


Figure 10. Trends in offshore biomass indices from (a) the west coast of Vancouver Island shrimp survey, (b) the Queen Charlotte Sound shrimp survey, and (c) the Hecate Strait groundfish assemblage survey. The inserts in Panel A show the approximate geographic areas for the three biomass estimates. Figures (a) and (b) are adapted from a DFO website(http://www-ops2.pac.dfo-mpo.gc.ca/xnet/content/shellfish/shrimp/Surveys/0902.pdf). Figure (c) is from Sinclair *et al*. 2007.

Trends in the offshore indices of abundance do not match trends in spawning abundance in adjacent rivers (described below). In particular, spawning abundance did not increase during 2001-2004 as would have been expected from the peak in offshore indices. It is difficult to explain these differences in trend.

Another remarkable aspect of the offshore biomass estimates is the apparent disparity with spawning estimates. Marine biomass estimates are in the range of several thousand tonnes while spawning runs in similar periods are estimated to be in the range of several tens of tonnes. This phenomenon also occurs in Alaska (Ormseth *et al.* 2008). For instance the estimated abundance of Eulachon in 2003 in the central area of the Gulf of Alaska was almost 95,000 t and more that 113,000 t for the entire Gulf. The estimate is many times greater than the apparent spawning biomass in the largest rivers, such as the Copper River.

The differences in trend and scale of indices of offshore abundance and estimates of spawning abundance may be related to factors such as marine survival of juveniles, offshore survey methodology, larval survey methodology, and the river of origin of the offshore samples. Offshore catches mainly comprise two immature age groups that would have remained in the marine environment for another 1 to 2 years before maturing and returning to fresh water to spawn. Thus, these cohorts could have experienced substantial and variable mortality at sea after the offshore surveys occurred. The offshore surveys were not designed for Eulachon and may not be an effective tool to measure their abundance. The larval survey methodology does not account for egg and larval mortality and may therefore underestimate spawning biomass. A better understanding of the reasons for the discrepancy between offshore indices and spawning abundance estimates may be especially important to understanding factors affecting Eulachon survival. However, this report will focus mainly on estimates of the spawning population abundance and trends.

General abundance trends

Moody (2008) used a fuzzy logic expert system to compile estimates of the relative abundance of Eulachon in 15 rivers. The methods and structure of the expert system were based on a previous expert system by Cheung *et al.* (2007). Diverse sources of quantitative data from scientific surveys, reports and literature and qualitative or semi-qualitative records from interview surveys or historical archives were collected. These data represented direct or indirect proxies of relative abundance of each Eulachon river, varying from one to eight possible data sources. All information was combined to estimate an abundance status index for each river. The amount of data used for annual estimations depended on the availability of data for each area, varying from one to a maximum of eight possible data sources (e.g., catch data or qualitative run size information). The final annual abundance indices were estimated by combining the abundance levels derived from each available data source, based on designed heuristic rules and by adjusting weighting parameters. The analysis included the period 1927 – 2006, and the results were summarized in 4, 20-year, colour-coded, tables for the 15 rivers. Results indicated that declines in relative abundance were larger and longer (i.e., > 5 years) during the most recent 20-year period for many Eulachon rivers, particularly in the southern part of the range (i.e., Klamath River, California; the Columbia River, Washington and Oregon; the Fraser River, BC) and the smaller rivers (i.e., the Bella Coola River, BC; the Wannock River, BC; and the Unuk River, Alaska).

Abundance trends for each designatable unit

Temporal trends in the abundance indices (*A*) presented here were assessed with a log-linear regression, specifically the natural logarithm of the abundance index was regressed against year and the regression slope parameter (β) was used to estimate the change in abundance. The regression equation in this case was

$$\ln(A_Y) = \alpha + \beta Y$$

where α is the regression intercept and Y is the index year. There were two abundance indices presented for the Nass River DU. An analysis of covariance was used to estimate the change in abundance in this case

$$\ln(A_{YI}) = \alpha + \alpha_1 I + \beta Y$$

where I is a class variable indicating the index source. The method estimates separate intercepts for each index and a common slope.

The COSEWIC decline criterion requires the calculation of a decline in spawning population over the larger of 3 generations or 10 years. Given that the Eulachon generation time is 3 years, declines are calculated here over a 10-year period. If there were data for a longer period, the decline rate was also calculated for the entire time period for illustrative purposes. The percent change in abundance (Δ) over a period of t years was estimated using the equation

$$\Delta = 100(\exp(t\beta) - 1)$$

Nass/Skeena DU

There are three Eulachon rivers in this DU, Bear, Nass, and Skeena. The status of this DU was determined based on information from the Nass and Skeena Rivers because very little is known about Eulachon in the Bear River, and the runs there are not regular (Anon 2006). The IAO for this DU was not calculated as there was no readily available information with which to do this calculation.

The Nass River in northern BC is one of the largest Eulachon runs and is fished mainly by the Nisga'a people. The Nass run arrives around mid-March, but a possible second run might arrive in early April (Langer *et al.* 1977). River conditions vary from year to year during the Eulachon season, and fluctuate between completely free of ice to complete ice blockage. Fishing success in this area depends on the weather and ice conditions. In the past, Eulachon were commonly harvested through the solid ice with large conical nets, but if the ice was too thin or broke up during the main run, fishing stopped until the ice cleared and was then conducted from boats (McNeary 1974).

The Nass River has supported large catches of Eulachon, both by First Nations and a commercial fishery in the early 1900s. In the early 1840s it was reported that "the Tsimshians brought more that 30,000 gallons of oolachan oil to Fort Simpson annually" (Gibson 1992). If this amount is converted to tonnes of fresh Eulachon, using the parameter 14.08 gallons/t of fresh Eulachon (Moody 2008) this would equal approximately 2,100t of Eulachon. This is probably an accurate estimate for this time period, as others reported that the "Indian fishermen land[ed] thousands of tons" of Eulachon a year (Collison 1916). There are no biomass estimates for the Nass River Eulachon spawning runs. However, assuming that the spawning biomass of Eulachon was at least twice as large as the highest catch, the Nass River might have had a spawning biomass of about 4000t, or roughly 100 million mature fish (at 40 g each).

Catches in the Nass River from 1929-2009 were taken from several sources (Hay and McCarter (2000), Moody (2008), and LGL Limited). These are plotted in Figure 11. Several years are missing data and could not be plotted. The low value in 2006 was due to heavy ice in the river. If one excludes the very low values, it may be said that catch averaged approximately 300 t annually in the 1950s and 1960s, and around 200 t in the 1990s and 2000s.

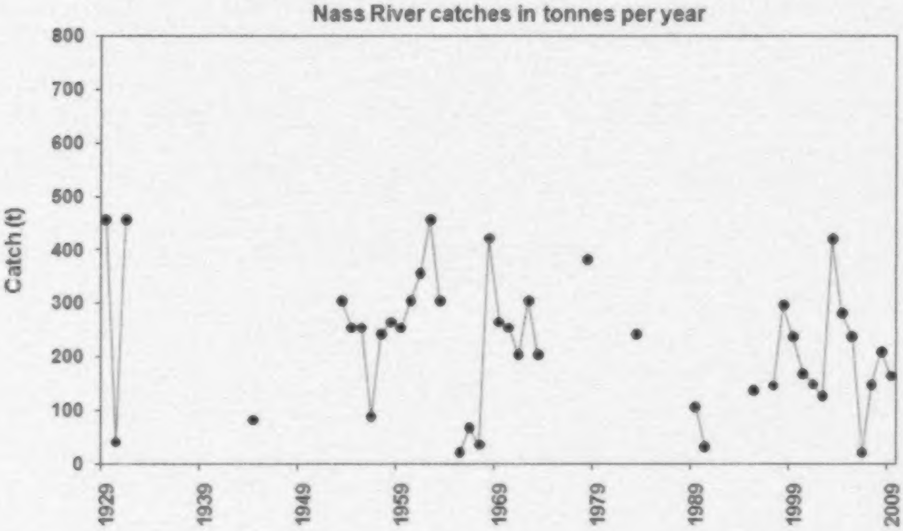


Figure 11. Long-term series of catch data (t) by year in the Nass River. Data from 1929-1996 were taken from Hay and McCarter (2000) and Moody (2008), Data for 1997 – 2009 were provided by LGL Limited.

LGL, a consulting firm that monitors catches for the Nisga'a and Tsimshian First Nations, provided data of annual Eulachon catch and fishing effort from 1997-2009 (Table 5, Figure 12). Catch by the Nisga'a First Nation averaged about 180 t annually with no apparent trend while those of the Tsimshian First Nation were smaller, averaging 27 t. Catch in 2006 was very small in both fisheries due to heavy ice conditions. Fishing effort in the Nisga'a fishery was somewhat higher in the period 2005 – 2009, averaging 390 hours per year, than in the period 1997 – 2004 when the annual average was 213 hours. The catch per unit effort (CPUE) in the Nisga'a fishery was very high in 2004, but the values in 2005, 2007 – 2009 were generally less than those in 1997 - 2002. CPUE was low in both fisheries in 2006; however, this was due to heavy ice conditions. The 2006 data were not included in the trend analyses below.

Table 5. Estimates of Eulachon catch in the Nass River by the Nisga'a and Tsimshian First Nations (Nisga'a fisheries data provided by Richard Alexander, LGL Limited environmental research associates).

	Nisga'a Catch (t)	Tsimshian Catch (t)	Total Catch (t)	Nisga'a Effort (hrs)	Tsimshian Effort (hrs)	Nisga'a CPUE (t/hr)	Tsimshian CPUE (t/hr)
1997	128.21	18.00	146.21	95.32	13.00	1.35	1.38
1998	214.90	81.00	295.90	226.50	145.50	0.95	0.56
1999	222.16	15.02	237.18	255.57	39.75	0.87	0.38
2000	152.33	15.41	167.74	404.40	52.50	0.38	0.29
2001	149.43	0.00	149.43	205.02		0.73	
2002	116.76	9.60	126.36	162.80	116.00	0.72	0.08
2003	350.00	70.00	420.00				
2004	257.48	23.95	281.43	143.00	63.50	1.80	0.38
2005	239.93	0.00	239.93	354.50		0.68	
2006	21.44	0.44	21.87	271.86	24.13	0.08	0.02
2007	145.87	2.13	148.00	505.00	44.00	0.29	0.05
2008	174.39	34.83	209.22	397.21	96.63	0.44	0.36
2009	164.07	0.00	164.07	418.09		0.39	
Mean	179.77	20.80	200.57	286.61	66.11	0.72	0.39

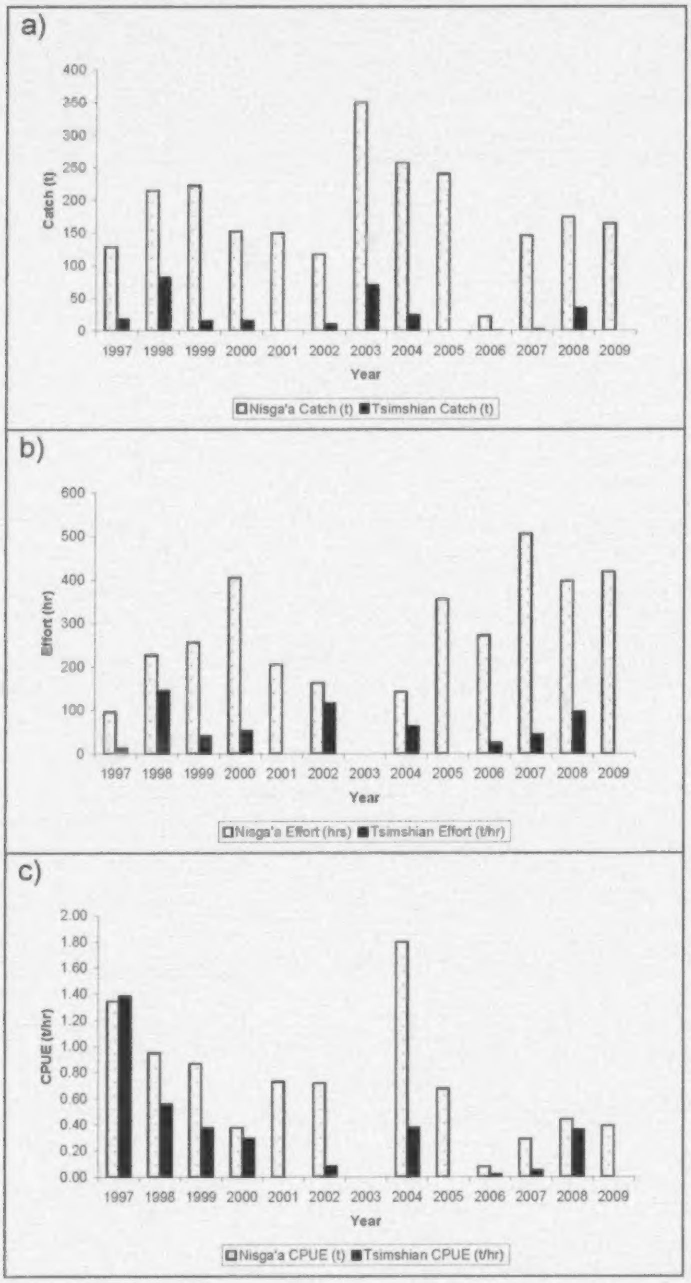


Figure 12. Catch (a), effort (b), and catch per unit effort (c) by Nisga'a and Tsimshian fishers by year in the Nass River for 1997 - 2009. Data were provided by LGL Limited.

The log-linear analyses of the CPUE time series were restricted to the last 10 years of data, i.e., 1999 – 2009. The Nisga'a CPUE time series produced a non-significant slope estimate of -0.0608 ± 0.1256 yr^{-1} ($p = 0.29$). The Tsimshian CPUE time series produced a non-significant slope estimate of -0.0726 ± 0.3271 yr^{-1} ($p = 0.57$). The combined CPUE analysis using an analysis of covariance produced a non-significant slope estimate of -0.0654 ± 0.1156 yr^{-1} ($p = 0.24$). This slope suggests a decline in run size of 48% over the last 10 years; however, this estimate has a large degree of error and it must be interpreted with caution. If the entire time period was used (1997 – 2009) the combined analysis produced a significant slope of -0.108 ± 0.0856 yr^{-1} ($p = 0.02$). At this rate, the decline in run size would be 66% over the past 10 years.

Moody (2008) concluded that Nass Eulachon abundance was stable in recent years.

It should be noted that the current abundance of Eulachon in the Nass River must be considerably lower than it was 100 – 200 years ago. The largest reported catches were in the range of 2000 t annually in the early 1840s. Recent catches have averaged 200 t annually. These are the lowest catches on record.

From 1924-1946, the Canadian Bureau of Statistics recorded commercial Eulachon harvests from the Skeena area. These catches ranged from 17.3 t in 1924 to 1.0 t in 1935 (Canada 1917-1976). All other Eulachon fisheries in this area were traditionally conducted by members of the Tsimshian First Nation, whose members include: Metlakatla, Lax Kw'Alaams, Kitsumkalum and Kitselas Bands (Ryan 2002). The Ecstall River was the only river harvested by the Tsimshian for the production of Eulachon grease because they were said to be of a different or 'better' quality than the Skeena Eulachon (Don Roberts, Kitsumkalum member pers. comm. 2006). Experienced harvesters from the area report that the run was historically small and short-lived and Tsimshian members usually obtained most of their Eulachon from the Nass River (Roberts 1997). During the 1950s Prince Rupert DFO Fisheries Officers reported that Eulachon of the Skeena and Ecstall rivers were "not fished commercially or for food purposes" (DFO 1941-73).

The Skeena River is the second largest river in BC but it is difficult to monitor for Eulachon. According to Lewis (1997) the Skeena River run has historically been very short-lived and difficult to harvest. The Eulachon historically returned to the Skeena during the first week of March; however, in the past decade, it has occasionally returned earlier, during mid- to late February (Don Roberts pers. comm. 2006). By the mid-1990s the run to the Skeena area noticeably declined, with very few Eulachon observed or caught between 1997 and 1999 (Don Roberts pers. comm. 2006). It has also been noted that spawning in upstream areas has diminished. A study on Eulachon life history, habitat use and spawner abundance was conducted on the Skeena River during the 1997 season; the run was estimated at 3.0 t (Lewis 1997). Beginning in 2000, the Tsimshian Tribal Council monitored the status of the Skeena Eulachon using plankton tows for the capture of eggs and larvae and gillnets to capture adults. The crew also monitored the water temperature and the salinity of all three rivers. Relative to the recent 10-year average a "good" run was observed in the area in 2005, although, in 2006 there was virtually no run to the Skeena River (Don Roberts pers. comm. 2007).

Central Pacific Coast DU

The central DU comprises 34 Eulachon rivers and spans 600 km of coastline (Figure 1 and Table 1). The available information on abundance trends and status is grouped by geographic area to facilitate discussion. Only rivers for which information exists are discussed below. The IAO for this DU was not calculated as there was no readily available information with which to do this calculation.

Kitimat and Kildala Rivers

The Kitimat and Kildala Rivers are located in Douglas Channel. The Haisla First Nation historically harvested Eulachon in both rivers. The Eulachon usually returned to the Kitimat River during the middle of April (Starr 1983). Eulachon grease had previously been produced in the 'Old Village' of Kitamaat. A report by Tirrul-Jones (1985) estimated past catches of Eulachon as follows: "at least 40 nets set at one time and [if] worked seven days...each net would catch a minimum of 1.8 t with 40 nets working 508 t of Eulachon were caught in a week's time." This estimate of 500 t is speculative and based on some assumptions about average catch rates. Annual catches from the Kitimat River, reported by DFO Fisheries Officers from 1969-1971, ranged between 27.2 t and 81.6 t. Eulachon fishing was curtailed on the Kitimat River in 1972 as pollution by industrial and municipal effluent discharges made the Eulachon foul-tasting and inedible (Tirrul-Jones 1985). Since then, the people from the Haisla First Nation have travelled to the Kemano River or the Kildala River to harvest Eulachon, although in recent years these too have suffered major declines.

Since the 1970s the abundance of Eulachon in the Kitimat River has declined. There are a number of consulting reports on the Kitimat River (see Hay and McCarter 2000 for a summary to 1999) but few explicitly comment on abundance. The last strong run to the Kitimat River occurred in 1991 and runs from 1992-1996 were estimated at half the size of 1991 (Farara 2000). Also, a DFO report by Pederson *et al.* (1995) provides a simple, approximate estimate of spawning abundance for a single year (1993) equal to 22.6 t or about 514 thousand mature fish. This is significantly less than inferred from past harvests.

An informative time series of Eulachon catch data for the Kitimat River was collected by consultants working for the pulp mill in Kitimat. The data were provided by Dennis Farara, Ecometrix, Toronto. A summary of Eulachon catches, captured by annual routine sampling procedures since 1993 is shown in Table 6 and Figure 13. The 2006 run was the lowest recorded and was virtually non-existent. There was a precipitous drop in the total catch, and CPUE, between 1996 and 1998. The average CPUE in the period 1994-1996 was slightly more than 80 times the average for the period 1998–2007. A log-linear regression fitted to the data from the last 10 years (1998-2007) had a non-significant slope of -0.149 ± 0.258 yr^{-1} ($p = 0.22$). This slope suggests that the run has declined by 77% over the last 10 years; however, this estimate must be treated with caution given the high estimation error. On the other hand, the run sizes in the past 10 years were extremely small compared to those immediately preceding them. A log-linear regression fitted to the data for the period 1994 – 2007 produced a significant slope estimate of -0.445 ± .206 yr^{-1} ($p < 0.001$). This slope suggests the run has declined by more that 99% over that 13-year period. The present spawning biomass is also estimated at zero.

Table 6. Eulachon catches and estimated CPUE in the Kitimat River (Ecometrix Areas G2 and G3 for March, 1994 to 2007) made by systematic gillnet collections, 1993-2007 (data were provided by Dennis Farara, Ecometrix, Toronto).

Year	Total Catch	CPUE
1994	1257	59.86
1995	2157	56.76
1996	1547	49.87
1998	27	0.90
1999	25	0.61
2000	31	0.25
2001	174	1.54
2002	41	0.44
2003	121	1.17
2004	33	0.27
2005	141	0.96
2006	5	0.04
2007	92	0.37

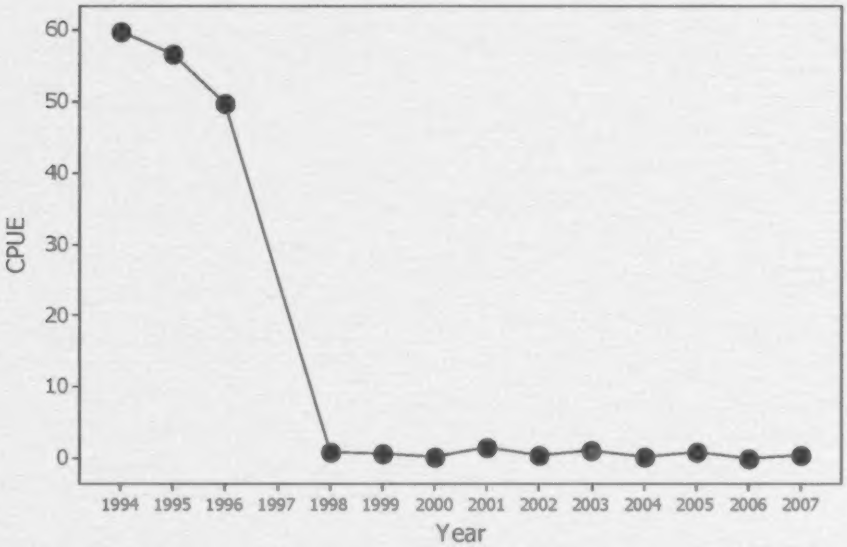


Figure 13. Catch per unit effort of fishing in the Kitimat River. The catches were made with a gillnet set for timed periods (data from D. Farara, Ecometrix, Toronto). There were no data collected in 1997.

Kemano-Wahoo Rivers, Kowesas and Kitlope Rivers

The Kemano, Kowesas and Kitlope Rivers are located in Gardner Canal. The Haisla Fisheries Commission has monitored the Kowesas and Kitlope Rivers intermittently over the past two decades and the Kemano River annually since 1988 (Lewis *et al.* 2002; Lewis and Ganshorn 2004).

The Kemano/Wahoo confluence is made up of the Aluminum Company of Canada (Alcan) Kemano powerhouse discharge and the flow from the Kemano River and its tributaries. As part of an environmental management plan, Alcan has monitored the abundance of Eulachon and worked cooperatively with the Haisla First Nation to monitor the Eulachon fishery (Lewis and Ganshorn 2004).

The Haisla people and their guests, comprising several bands of First Nations located throughout the Kemano and Kitimat valleys, fish this river system. Harvesting is conducted using mainly seine nets and dip nets; however, the traditional Takalth net (conical net) is used occasionally as an indicator of abundance.

DFO annual narrative reports indicate that Kemano River Eulachon catches from 1969 to 1973 averaged 44.3 t (range between 18.1 t to 81.7 t, Table 7, Figure 14a) annually (DFO 1969-1973). More recent catch and effort data sets (1988 – 2007) were provided by A. Lewis, based on work conducted for Alcan. Kemano River catches were highly variable during this period, varying between a high of 93 t in 1993 and less than 5 t in 2000 and 2002 (Figure 14a). Although the catches since 2005 have been virtually zero, small numbers of Eulachon were seen in the vicinity of the Kemano estuary in 2007 but they did not ascend the river (comment made by Ken Hall, member of the Haisla Nation during the Eulachon Crisis Meeting held in Bella Coola, BC June 10-11 2007). Similar observations were reported in 2009 (Adam Lewis pers. comm.). Much of the variation in catch was related to variation in fishing effort (Figure 14b). The relatively high catches in 1995, 1996, 2004, and 2005 resulted from the four highest levels of effort. The CPUE declined irregularly during the years 1988 to 2007 (Figure 14c). There was a large decline between 1993 and 1994, followed by an increase to 1998. CPUE was very low in 2000 – 2002, was somewhat higher in 2003 and 2004, then very low again in 2007.

Table 7. Time series of catches and CPUE estimated for the Kemano River, BC. Data for 1988-2008 were provided by Adam Lewis on behalf of Alcan Ltd., and DFO annual narrative reports were the sources of data for 1969-1973. The 2009 data points were based on personal communication with Adam Lewis. The 'adjusted catch' (Column 2) means that hailed data from fishers were calibrated by the ratio of measured/hailed catches based on a subset of measured data. The adjustment was used because of a slight tendency of fishers to overestimate catch when hailing catch weights.

Year	Adjusted Catch (t)	Effort (sets)	CPUE (t/set)
1969	30.8		
1970	45.4		
1971	18.1		
1972	45.4		
1973	81.7		
1988	43.2	19.9	2.2
1989	50.2	18	2.8
1990	44.1	25	1.8
1991	57.2	18	3.2
1992	65.4	19	3.4
1993	93	34	2.7
1994	20.6	23	0.9
1995	69.2	79	0.9
1996	81	57	1.4
1997	41.9	22	1.9
1998	61.7	27	2.3
1999			
2000	1.76	11	0.2
2001	5.1	13	0.4
2002	2.9	15	0.2
2003	73.9	62	1
2004	59	64	0.5
2005			
2006			
2007	0.2	<1	~0.1
2008			
2009			

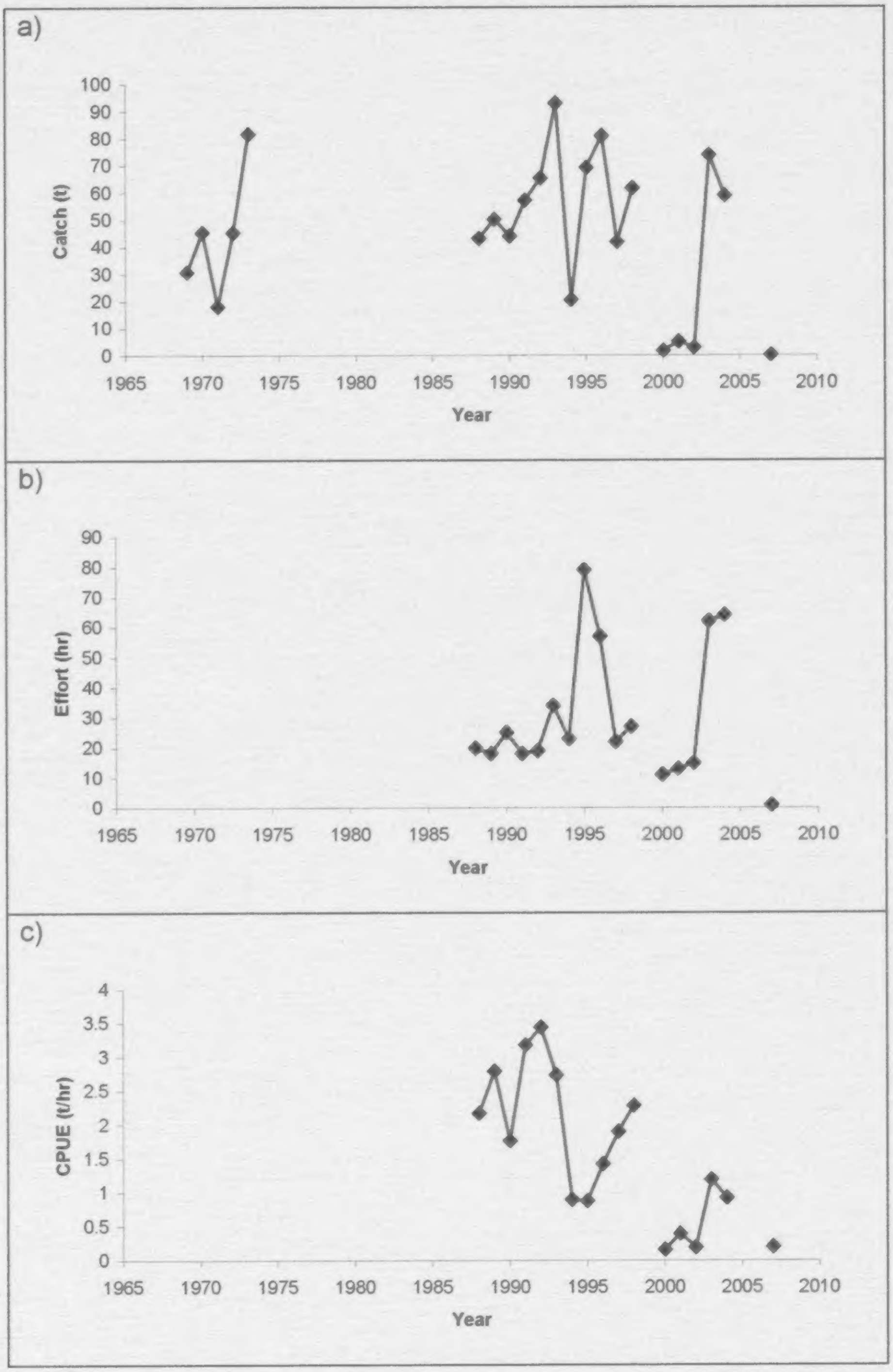


Figure 14. Total catch (t) (a), fishing effort (hr) (b), and CPUE (t/hr) (c) in the Kemano River (see Table 7 for data sources).

A log-linear regression fitted to the CPUE data for the last 10 years (1997-2007) had a non-significant slope of -0.245 ± 0.246 yr^{-1} (p = 0.051). This slope suggests that the run has declined by 91% over the past 10 years. However, this estimate must be treated with caution given the high estimation error. On the other hand, the present spawning biomass is estimated at virtually zero. If the entire time series is used (1988 – 2007) the slope estimate was highly significant at -0.155 ± .062 (p=0.001). If that rate is applied to the last 10 years, the estimated decline is 79%.

North and South Bentinck Arms, Dean Channel and Kwatna Inlet

Ten rivers in the Bella Coola area were known to have Eulachon spawning populations: Bella Coola River; Paisla Creek and the Necleetsconay River of North Bentinck Arm; Dean and Kimsquit Rivers in the Dean Channel; Aseek, Taleomy, and Noeick Rivers of South Bentinck Arm; and Kwatna and Quatleena Rivers of Kwatna Inlet. Historically, the four largest runs were the Bella Coola, Kimsquit, Taleomy and Kwatna Rivers. These were also locations of old Nuxalk village sites.

Prior to the infectious disease epidemics of the late 1800s, these villages were inhabited and Eulachon were harvested annually. However, when the Nuxalk populations were decimated, the survivors were relocated to the Bella Coola area, and the Bella Coola River was the only river fished regularly for Eulachon. Thus the majority of information for this area comes from the Bella Coola River.

DFO kept records of Eulachon catches between 1945-1983 (Hay and McCarter 2000) and in general annual catches were about 15 t per year, although in some years, catches exceeded 60 t. These records, however, may not have been complete or collected consistently. The present status of the Bella Coola River has been reviewed thoroughly by Moody (2008). The Eulachon run has been virtually non-existent in the Bella Coola for nearly a decade. Figure 15 (from Moody 2008) provides a quasi-quantitative estimate of the run size between 1945 and 2006 using an arbitrary scale of 10 indicating relative abundance. The decline rate over the entire data record was estimated to be -1.5% yr^{-1}. However, the plot indicates an increased rate of decline after about 1975. Since then, the estimated decline rate was -3% $year^{-1}$. The rate of decline would be steeper if examined over a shorter period during the most recent years (i.e., 1990-2000). Eulachon failed to return in large numbers to the Bella Coola River in 1999 and for the past 10 years this pattern has continued.

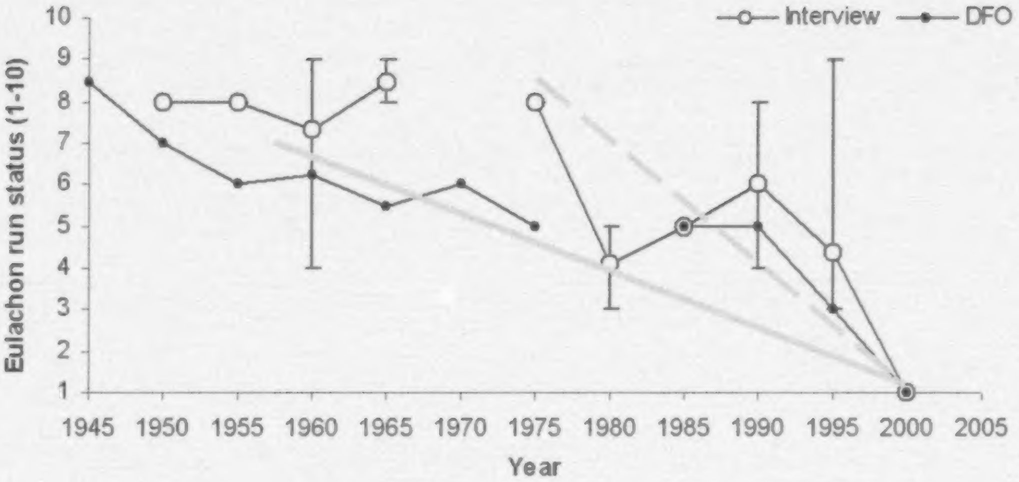


Figure 15. Abundance trends in the Bella Coola River, 1945-2006 (adapted from Moody 2008). The ordinate is based on an arbitrary scale of 10 indicating relative abundance. The dotted line represents the decline rate over the 60-year data record for an approximate rate of 1.5% year^{-1}. The grey dashed line represents the approximate decline since about 1975 (30 years) for an approximate decline rate of 3% year^{-1}. The rate of decline would be steeper if examined over a shorter period during the most recent years (i.e., 1990-2000).

The absence of any significant run in the past 8 years has been documented by unpublished annual reports and a 7-year review report (2001 to 2007) describing egg and larval survey estimates of relative spawning biomass (Moody 2009). From 2001-2007 the annual spawning stock biomass was estimated at less than 200 kg. The Nuxalk Nation of Bella Coola has conducted these annual field surveys to assess the distribution and abundance of the Bella Coola Eulachon population, to collect samples for DNA analysis, and further develop capacity for local management, research and planning activities. These projects confirm that the Bella Coola Eulachon runs are extremely low. Due to insufficient numbers of spawning fish the Nuxalk community has not conducted a food fishery since 1998.

Rivers Inlet

The Rivers Inlet area has four known Eulachon rivers: (1) Wannock River; (2-3) Chuckwalla River and Kilbella Rivers of Rivers Inlet, and (4) the Clyak River at the head of Moses Inlet, located just north of Rivers Inlet. A large run previously returned to the Clyak River but has not been observed since the 1940s (Winbourne and Dow 2002). The Eulachon of this area were only harvested by the Wuikinuxv Nation (previously spelt Oweekeno Nation). However, in the Canada Sessional Papers it is reported that smoked Eulachon and barrels of salted Eulachon were taken from the Rivers Inlet area and transported to the Skeena District between 1888 and 1892 (Canada 1878-1914). The amounts ranged between 200 and 2000 lbs (0.09 t and 0.9 t) of smoked Eulachon and between 75 and 125 barrels of salted Eulachon.

The Wuikinuxv village is located on the Wannock River, between Oweekeno Lake and the head of Rivers Inlet. Because of accessibility, the Wannock River was the most regularly fished of the four rivers. The lower reaches of the Chuckwalla and the Kilbella rivers were usually only fished when the Wannock run size was small. Harvests by the Wuikinuxv people are small compared to other areas on the Pacific Coast but this may reflect a small village population rather than a small Eulachon run.

The only catch figures reported for these rivers were found in Fisheries Officers' annual narrative reports for the years 1967, 1968 and 1971, with catches of: 1.81 t, 2.27 t and 4.54 t on the Wannock (DFO 1967-68 & 1971). The runs during the early 1960s were also described by Fisheries Officers as being "sufficient" and "adequate" to meet the needs of the Wuikinuxv people.

Community members interviewed in the 2002 Central Coast Eulachon project reported that the run to the Wannock River had been gradually declining since the 1970s (Winbourne and Dow 2002). The last fishable run occurred in 1986 (Burrows 2006). However, the run has been "poor" since 1994 (Frank Johnson pers. comm. 2007). In 1997, a study was conducted on the Wannock River in an attempt to measure the spawning biomass. However, virtually no Eulachon eggs or larvae were found in any of the 376 samples taken from the river (Berry and Jacob 1998). In spite of this, the Wuikinuxv community members caught approximately 150 kg of Eulachon from the Kilbella and Chuckwalla rivers in 1997 (Berry and Jacob, 1998). Also in 1997, Eulachon larval surveys were conducted in Central Coast mainland inlets, Rivers and Smith inlets being two of those sampled. The combined spawning biomass of these two areas was estimated at 6.46 t (McCarter and Hay 1999).

Since 1997, no Eulachon have been harvested in the Rivers Inlet area. To determine the current abundance in 2005 and 2006, the Wuikinuxv Fisheries Department conducted spawner abundance surveys on the Wannock River. Only eleven adults were captured in 2005, with an estimated 2,700 adults (0.1 t) returning to spawn (Burrows 2005). In addition, three adults were captured in the Kilbella River (Burrows 2005). In 2006, the study was repeated, with no adults captured, although nets were removed early because of requests made by elders, and an estimate of 23,000 adult spawners was calculated (Burrows 2006).

Smith Inlet

Smith Inlet had never been previously recorded as possessing a Eulachon run, but the results from McCarter and Hay (2003) indicate that there may be a small Eulachon run in the area because larvae were captured in ichthyoplankton tows. The Nekite River, located at the head of Smith Inlet, is most likely the Eulachon-bearing river in which these larvae originated. In a later study a single Eulachon larva was found during in-river plankton tows (conducted as part of a study directed mainly at Bella Coola Eulachon (Winbourne and Dow 2002)).

Johnstone Strait

The northern Johnstone Strait area has six known Eulachon rivers: (1) the Kingcome River of Kingcome Inlet; (2-3) the Klinaklini and Franklin Rivers of Knight Inlet; (4-5) the Stafford and Apple Rivers of Loughborough Inlet; and (6) the Homathko River of Bute Inlet.

In 1997, larval surveys were conducted in this region, and larvae were found at the head of Thompson Sound, suggesting Eulachon spawning in the nearby Kakweiken River (McCarter and Hay 1999), thus identifying this river as another potential Eulachon spawning river for the region – for a total of seven rivers. The Eulachon migration to these areas occurs during April, with the peak of abundance returning by the middle of the month (Common Resources Consulting Ltd. 1998).

Kingcome River catches have occasionally been included with Knight Inlet catches. However, when reported separately, they were estimated at around 9 t annually (1960 and 1966) (Common Resources Consulting Ltd. 1998). Declining runs in the Kingcome River were first reported in 1973, as a “very small” run was seen in 1971 and “light catches” were reported in 1972 (Common Resources Consulting Ltd. 1998). There is limited documentation for this river after 1977 and throughout the 1980s.

A 1997 study on the Kingcome River, estimated the biomass at 14.35 t (360 thousand mature fish), thought to be a fraction of past runs (Berry and Jacob 1998). Larval surveys conducted in 1994 and 1997, estimated the approximate Eulachon spawning biomass of the Johnstone Strait Region at 107 t and 48 t, suggesting a greater than 50% decline in abundance between the 3 years (McCarter and Hay 1999). By 2000, the Kingcome run was reported to be “poor or nil” (Hay and McCarter 2000). However, in 2001 the Kingcome run improved and was considered “good” in 2002, with approximately 330 gallons of grease produced (Nicolson 2002). Since then the run has fluctuated. Midori Nicolson, a member of the Tsawataineuk First Nation and a participant in the Kingcome Eulachon fishery, confirmed that the 2003 and 2004 seasons were poor and only an average run was seen in 2005 (Midori Nicolson pers. comm. 2007). In 2006, the Kingcome run was absent and only small returns were seen in 2007 (Midori Nicolson pers. comm. 2007). Nicolson provides a short time series of relative Eulachon abundance in the Kingcome River (same data as used by Moody (2008)) and this is shown in Table 8. The quantitative scale beside each year represents an approximate scale of abundance. In 2007, “Of the three major camps in Kingcome, only one camp made some grease but the fishery was stopped due to low numbers, once the females had passed. Some fish were caught, but none were preserved or made into grease. Therefore the year 2007 cannot be assumed to be relatively good, although Eulachon were spawning in the river” (Midori Nicolson pers. comm.).

Table 8. Estimated trends in Eulachon catch (t) in the Kingcome River. The reference to 'gallons' is to grease production (data provided by Midori Nicolson).

1993	1
1994	1
1995	1
1996	0
1997	2
1998	4
1999	4
2000	0
2001	4
2002	6 – 330 gallons
2003	1
2004	1
2005	5
2006	0
2007	4

There are two Eulachon-producing rivers in Knight Inlet, the Klinaklini and the Franklin. The former was the most important. In the late 1800s, the Kwawkewlth were recorded to have harvested immense quantities for food, oil and as articles of trade (Swan 1885). In the early 1900s, the annual combined grease production of Knight and Kingcome Inlets was approximately 1500 gallons (Curtis 1915). When this amount of grease is converted to fresh weight using Moody's (2008) parameter (14.08 gallons/tonne of fresh Eulachon) the catch equals approximately 100 t, and this is comparable with years of high catches recorded by DFO between 1943 – 1977 (Figure 16). The Klinaklini River run in Knight Inlet was generally larger than that of the Kingcome River. This can be seen in the annual catches recorded from each river (Figure 16). There were a few years of commercial catches of Eulachon in this area in the late 1940s. The commercial catches were used for food in the fur farm industry (Common Resources Consulting Ltd. 1998). This led to several separate demands by the First Nations in this area to reserve the Eulachon fishery for their exclusive "use and benefit" and to stop commercial fishing in the area (Common Resources Consulting Ltd. 1998). Thus commercial Eulachon fishing in the area was banned by DFO in 1948 to preserve "an ancient and traditional food supply for the Indians" (Common Resources Consulting Ltd. 1998). The only other Eulachon fishery in this area was conducted by white fishers from Sointula in 1957 and 1960 who supplied small quantities of Eulachon for fresh consumption to the local people in the Alert Bay area (Common Resources Consulting Ltd. 1998).

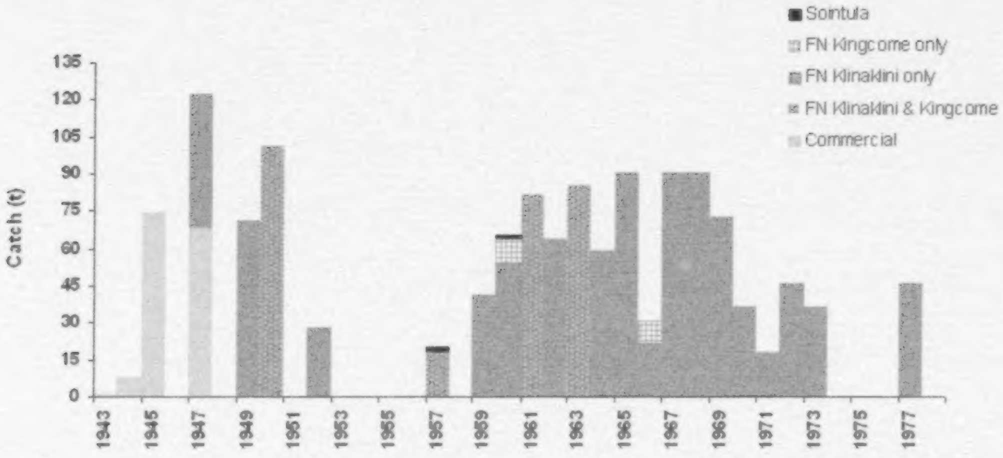


Figure 16. Eulachon catches from the Klinaklini and Kingcome rivers, 1943-1977 (from Moody 2008).

By the mid-1990s runs in the Klinaklini River were thought to be in decline (Hay and McCarter 2000). A 1996 study estimated the Klinaklini River's spawning biomass at approximately 40 t, which was thought to be approximately 15% of the historic run size (cited in Berry and Jacob 1998). By 2000, the Klinakilini run was reported to be "very low" (Hay and McCarter 2000). Robert Duncan, a member of the Da'naxda'xw/ Awaetlala First Nation and an Eulachon fisher witnessed low returns during the 2004 and 2005 seasons (Robert Duncan pers. comm. 2007). In 2007, the Klinaklini returns improved and, overall, it appeared to be a "very good run," (Fred Glendale pers. comm. 2007). In 2008, however, the run was judged to be very weak (W. Duncan pers. comm.). Adam Lewis (pers. comm.) sampled larval Eulachon in the Klinaklini and Franklin Rivers in 2009 and estimated the spawning biomass was 6.3 t in the Klinaklini and 0.3 t in the Franklin. Because the sampling was done late and because there also was a small fishery this estimate was probably conservative, by a factor of two or more. Generally, over the past few decades, the Klinaklini River has had low returns, although never a complete failure of the run (Fred Glendale pers. comm. 2007).

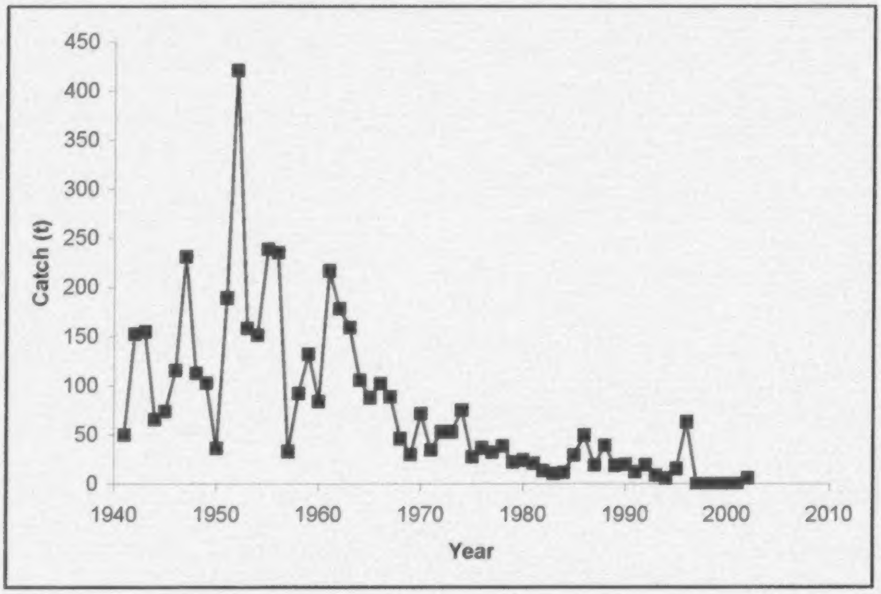
A rough estimate of the rate of decline of Eulachon in this area was determined in the following manner. It was assumed that the run size in 1969 was equal to two times the average annual catch for the period 1943 – 1969, excluding years for which catch data were unavailable and very low (see Figure 16). The average catch was about 90 t, giving a biomass estimate of 180 t. The run size estimates for 1996 (40 t) and 2009 (15 t) mentioned above were added. This suggests a decline rate of 6% annually, and a total decline over the last 10 years of 42%. While this decline is relatively low compared to that estimated for other areas, the data indicate a decline of over 90% since 1969.

The Squamish River is the most southerly in the Central DU. Very little is known about Eulachon here and the runs have not been documented.

Fraser River DU

Eulachon usually begin to ascend the Fraser River at the end of March and run until the middle of May (Ricker *et al.* 1954; Hay *et al.* 2005). Eulachon travel long distances up this river to spawn, the farthest known distance being Hope (154 km east of Vancouver) (DFO 1940-1979). However, more commonly they do not pass Chilliwack (100 km east of Vancouver) (Duff 1952) and the main spawning area seems to be between Chilliwack and Mission (Scott and Crossman 1973). Based on this information, the current area of occupancy is of the order of 216 km^2 based on a 2 x 2 km grid and 137 km^2 based on a 1 x 1 km grid of the area of the Fraser River between Mission and Chilliwack. The lower Fraser River is highly developed and susceptible to many threats that could rapidly affect the entire spawning population. Thus, the DU exists in one location.

The Fraser River Eulachon commercial fishery was the largest for the species in BC. During the period 1895 to 1904 the average annual catch was approximately 130 t (Ricker *et al.* 1954). Subsequent catches decreased abruptly to less than 45 t annually and this persisted until the early 1940s. The state of the Eulachon run became worrisome in 1939 when local fishers and buyers voiced concerns. This resulted in an investigation and the introduction of daily catch forms in the commercial sector (McHugh 1941). The conclusions of the 1939 investigation of catch statistics suggested the run had declined from 1921 to 1939 (McHugh 1939). From 1941 to 1954 the run was thought to have improved because there was a gradual increase in catch (Figure 17). An exceptionally high catch of 421 t was recorded in 1952 (Hay *et al.* 2003). The average annual catch between 1941 and 1959 was 144 t.



igure 17. Commercial fishery catches of Eulachon in the Fraser River, 1941 – 2002 (from Hay *et al.* 2003).

First Nations in this area noticed declines in the run since 1952, as the Eulachon were no longer seen spawning in some areas (Bailey 2000). From 1957 to 1961 the Eulachon run failed to return east of Mission and much concern was expressed in 1961 by Fisheries Officer J.B. Hawley, who worked in Mission-Harrison District: "No Oulachons have been reported in the Mission Area this month. I am of the opinion that the Oulachon run to the Fraser River is not receiving the protection it deserves. Numerous local fishermen are of the same opinion. These runs are no longer able to support a commercial fishery in my opinion" (DFO 1940-1979).

In response to demands made by the United Fishermen and Allied Worker Union and the Native Brotherhood of BC, and possibly due to the lack of Eulachon returning to their traditional spawning grounds, DFO announced changes to the regulations of the Fraser River Eulachon commercial fishery in 1957. The use of drag nets and trawls was banned, the commercial fishery was closed during the weekend, and portions of the Fraser River, east of Mission Bridge and a portion of Pitt River, were closed for commercial purposes (Anonymous 1957). Thus, the commercial fishery was limited to the use of drift gill nets, which commonly take more of the larger sized males, potentially benefiting the stock, as the smaller females get through (Anonymous 1957). Despite these changes in management, catches declined throughout the 1960s, 1970s and 1980s (Figure 17). A moratorium was requested by the Musqueam First Nation in 2004, and then later declared by DFO, due to conservation concerns (VISTA Strategic Information Management Inc. 1994). The fishery was allowed in 1995 and 1996, but was closed again in 1997 and commercial catches have only been taken in two of the last ten seasons, 2002 (5.76 t) and 2004 (0.44 t) (DFO 2006).

The First Nations and recreational Eulachon fisheries were estimated to catch 10 t annually during the 1980s and 1990s (Hay *et al.* 2003) although, at one time, a considerable portion of the Eulachon catch was taken by First Nations and local residents for personal consumption (McHugh 1941). Recreational and First Nation catch data are limited for the Fraser River. However, for the Mission District between 1956 and 1982 some reports are available from local DFO Fisheries Officers. The only First Nations catch reported separately came from the Steveston District, for the Musqueam First Nation (Figure 18), one of six Fraser River Eulachon fishing Nations. One year of recreational catch was found reported from the Steveston District, in 1981 (1,000 lbs or 0.45 t).

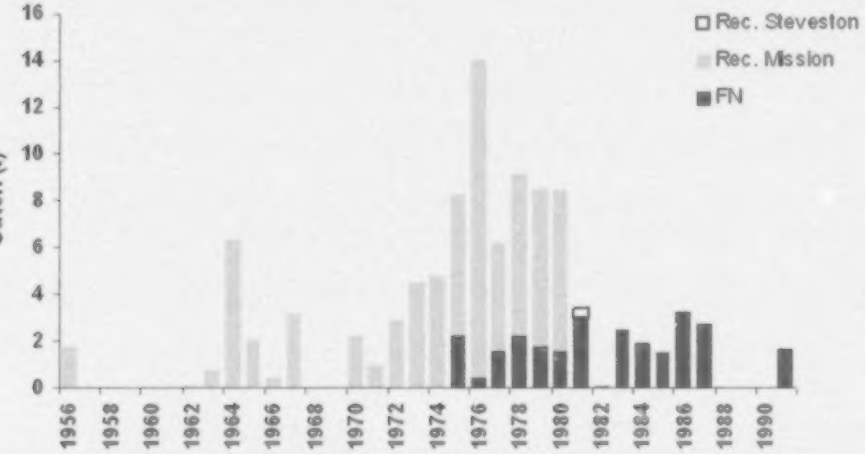


Figure 18. First Nations (FN) and recreational (Rec.) catches at Steveston and Mission, on the Fraser River (From Moody 2008).

The Fraser River egg and larvae surveys provide estimates of spawning biomass (DFO 2006) from 1995 to 2009 (Table 9, Figure 19). The highest biomass estimate was 1911 t in 1996 and the average biomass estimate was 482 t between 1995 to 2003. Since then, the biomass estimates have been very low, averaging 24 t between 2004 and 2009. A log-linear regression fitted to the data for the last 10 years (1999-2009) produced a statistically significant slope estimate of $-0.400 \pm 0.184\ \text{yr}^{-1}$ ($p = 0.0008$). Based on this, it was estimated that the population declined by 98% over the last 10 years. It should be noted, however, that the overall decline in Eulachon spawning biomass since the relatively successful commercial fishery in the 1950s would have been considerably higher.

Table 9. Estimated spawning biomass in the north and south arms of the lower Fraser River, based on systematic egg and larval survey methods described by (Hay *et al.* 2005). These data are available online: http://www.pac.dfo-mpo.gc.ca/sci/Herring/herspawn/pages/river1_e.htm (accessed March 3 2010).

Year	South Arm (t)	North Arm (t)	Combined Index (t)
1995	258	44	302
1996	1,582	329	1,911
1997	57	17	74
1998	107	29	136
1999	392	26	418
2000	76	54	130
2001	422	187	609
2002	354	140	494
2003	200	66	266
2004	24	9	33
2005	14	2	16
2006	24	5	29
2007	34	7	41
2008	8	2	10
2009	12	2	14

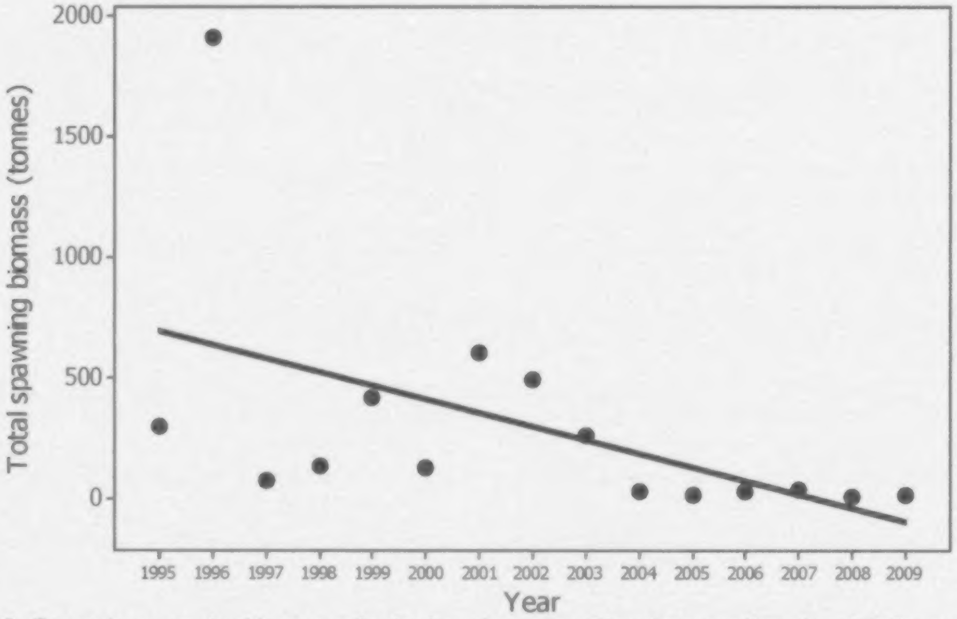


Figure 19. Fraser river spawning biomass estimates based on egg and larval surveys (based on data from a DFO website: http://www.pac.dfo-mpo.gc.ca/sci/Herring/herspawn/pages/river1_e.htm). The estimated spawning biomass in 2009 was 14 t. The assumptions and methods for these assessments are explained in Hay *et al.* (2002).

Synopsis of abundance trends in the three DUs

(1) Nass/Skeena DU. Eulachon abundance in the Nass River seems to be relatively high compared to other areas of the BC coast. However, 100-200 years ago the Nass supported annual catches as large as ten times current catches. The reported catch rates (t/hr) over the past 10 years have declined; however, the interannual variability is quite high. Another analysis (Moody 2008) indicates the Nass River population has been stable recently. There have been changes in spawning distributions in the Skeena River with reduced spawning in the upstream areas. Based on present observations of local fishers, the run size has decreased in recent years. Overall, the present Eulachon population may be as little as one tenth its historic size. While there is considerable variability in the CPUE data over the past 10 years, the available information indicates that run sizes have declined sufficiently to meet the Threatened criterion of between 30 – 50%.

(2) Central DU. Each river for which there are records has experienced drastic declines in run size, some to the point of virtual extirpation including the Kitimat, Kemano, Bella Coola, and those in Rivers Inlet. Substantial declines have also been documented for the Kingcome and Klinaklini rivers; however, there remain modest returns of Eulachon in these areas. Across the DU there have been severe and rapid declines in spawning abundance in the last 10 years with the disappearance of runs in several rivers.

(3) Fraser River DU. The Fraser River Eulachon spawning biomass reached an historic low of only 10 t (220 thousand mature fish with an assumed average weight of 45 gm) in 2008. The long-term average spawning biomass on the Fraser River may have been about 1000 t. Such a spawning biomass would have been able to sustain the relatively large catches that occurred during the middle part of the last century. Probably a maximum biomass could have exceeded 2000 t – or about the same as the biomass of about 1900 t estimated by egg and larval surveys (Hay *et al.* 2002). The present spawning biomass (2009) was estimated at 14 t. Based on the available spawning stock biomass time series, the 10-year decline rate was estimated to be 98%. There is one location in the DU and the IAO is 216 km^2.

Rescue effect

Little is known about linkages between Eulachon populations in Alaska and those in the Skeena DU. Thus it is difficult to determine the potential for rescue from populations to the north. Genetic data indicate a high degree of separation between Eulachon in the Columbia River and those in Canada. In any case, populations in Washington State and southeast Alaska are in a depressed condition (Appendix 1) so that rescue from populations to the south is unlikely.

Threats and limiting factors

When considering 'threats' to Eulachon it is important to remember that they are mainly a marine species, spending more than 95% of their lives in the sea and only using freshwater during spawning and egg incubation periods. In a few rivers there also may be a short larval period, but in most rivers newly hatched larvae are flushed to the sea very soon after hatching. It is simple to identify 'potential' threats and limitations in freshwater habitats but it is unlikely such threats, although often valid, would explain the nearly synchronous coast-wide decline of Eulachon that occurred in the early 1990s. It also would not explain why Eulachon in some rivers, with virtually pristine spawning habitats, have declined. Furthermore, the discontinuity between offshore indices of juvenile Eulachon abundance and indices of spawning abundance in coastal rivers suggests that variations in marine survival may be an important threat.

Spawning habitat

Probably spawning habitat is not limiting in most river systems. However, it is difficult to identify and classify Eulachon spawning habitat in some rivers because it seems that the fertilized eggs (embryos) are spatially dynamic, and move (or 'tumble') downstream in rivers. For instance the capture of live, unhatched eggs has occurred in every river system that has reported on the results of egg and larval surveys. The implication is that Eulachon eggs utilize broad expanses of the river bottom as they incubate. In large rivers, like the Fraser that require constant dredging to maintain shipping channels, it is important to restrict dredging to periods of the year when Eulachon are not spawning or when their eggs are incubating.

There are numerous threats to Eulachon spawning areas in the Fraser River. The river is highly developed industrially and residentially. Major road and rail transportation routes line the river banks and the river is navigable well above the range of the spawning migration. The river is often dredged for gravel extraction and to improve navigation. In the last two decades there is increased sensitivity regarding industrial and construction activity in the Fraser River during Eulachon spawning season. A possible example of that increased sensitivity and awareness of the spawning requirements of Eulachon are surveys that are conducted to attempt to determine Eulachon presence prior to activity such as gravel extraction that could potentially affect spawning habitat or spawning Eulachons (i.e., Plate 2009). On the other hand, a common misconception lingers that the precise spawning areas used by Eulachon can be found and avoided. Unfortunately, this may not be correct because Eulachon eggs often appear to be mobile in rivers even though they may be stuck to small pieces of debris. The evidence for this is the frequent capture, in most Eulachon rivers, of viable, developing Eulachon embryos in plankton nets. Evidently, the embryos develop during transit, a phenomenon called 'tumble incubation' (Hay *et al.* 2002).

There are several clear examples of habitat degradation associated with pollution. One is on the Kitimat River where industrial effluents have resulted in a contamination of spawning fish, making them inedible to traditional First Nations users. Another example is a study by Rogers *et al.* (1990) that describes uptake of chemicals by pre-spawning Eulachon in the lower Fraser River.

Predation

Eulachon have the highest-known lipid content of any marine fish species (Payne *et al.* 1999) so they make ideal prey and the concentrations of predators around migrating Eulachon runs is spectacular (Marston et al. 2002). There are several factors that warrant attention relative to potentially excessive predation on Eulachon. One is that in southern Georgia Strait the Harbour Seal population is at historical highs (Olesiuk pers. comm.). Harbour Seals and sea lions move into the lower Fraser River in massive numbers during Eulachon spawning runs. The extent of losses by such predation is uncertain, but is probably substantial. However, such focused predation does not necessarily occur in every river system and would probably not explain the widespread coastal decline of Eulachon.

Sturgeon also scavenge post-spawning moribund or dead Eulachon, but their predation is unlikely to affect the viability of the Eulachon population.

Marine survival, fisheries interception and bycatch

The ocean phase in the life cycle of Eulachon is the probable period when impacts have resulted in their decline. The discontinuity between offshore indices of juvenile Eulachon abundance and within river indices of spawning biomass indicates that mortality in the marine environment may be very important in determining the viability of the species. Eulachon aggregate in the sea and probably this is the main time when density-dependent, abundance-limiting factors become important. That phase in the life of a Eulachon is also relatively long – from the juvenile age of several months to the pre-spawning age of 3 years – allowing plenty of time for Eulachon populations to experience significant mortality. During this time Eulachon are found mainly in shelf waters, near bottom, probably feeding on zooplankton. There seems to be a physical association with shrimp distributions, and Eulachon are routinely taken as bycatch in shrimp trawls (Hay *et al.* 1997).

The rates of Eulachon bycatch in offshore shrimp fisheries were examined in several DFO reports (Hay *et al.* 1999; Olsen *et al.* 2000). There is significant variation in the rates of bycatch related to the types of shrimp fishing gear used. In general, the small beam trawlers, especially those that use 'low-rise' nets, tend to catch fewer Eulachon. Low-rise beam trawl nets with narrow vertical openings (the vertical distance between the lead line and the cork line) had lower rates of Eulachon bycatch than 'high-rise' nets that have larger vertical openings. The implication for this is that the vertical distribution of Eulachon might be slightly higher in the water column compared to shrimp, which would be closely associated with the bottom. In general, larger trawling vessels with 'otter trawls' (that use doors to spread the nets and thus tow at a faster speed to keep the net open) had higher bycatch rates.

Factors affecting bycatch rates are complex and poorly understood. In addition to the configuration of trawling gear, bycatch rates vary significantly with location, depth fished, season, and the use of bycatch reduction devices (BRD). Usually these are modifications to the fishing gear that allow Eulachon to escape from the top of the net before they are swept into the cod-end. In addition to the factors mentioned above, the vulnerability of Eulachon to trawl nets could depend on biotic factors, such as the availability or presence of food for Eulachon, or the presence (or avoidance) of predators. Probably oceanographic factors, such as water temperature and current velocity also affect bycatch rates.

The shrimp trawl industry has taken efforts to reduce bycatch through the use of BRDs, which are now mandatory. While these efforts are laudable they require more research to confirm their effectiveness, and also to determine whether or not Eulachon that escape through BRDs are injured in the process. This is seen as a vital question in other fisheries, especially those that use mid-water trawls where the small, young fish can escape through the meshes or though a BRD. For example, work by Suuronen *et al.* (1996) found very high rates of mortality, often exceeding 50%, of young Herring that escaped through trawls and other fishing gear used in the Baltic. Subsequently there has been a substantial research effort made to examine this issue in other species, which has resulted in the formation of specific committees to examine this question within the International Council for the Exploration of the Sea, the main international fisheries organization in the North Atlantic.

Although Eulachon bycatch in shrimp nets remains a concern, it should not preclude examination of other factors that may affect Eulachon in the marine environment, including mid-water and bottom-trawl nets used for other species. Also, the role of changes in the physical environment that affect Eulachon mortality are largely unknown. A better understanding of the marine ecology of Eulachon would provide useful information about factors controlling their distribution and abundance.

In-river fisheries also constitute a threat, especially in areas where run sizes are severely depressed and when removals are made before spawning takes place.

SPECIAL SIGNIFICANCE

Significance to First Nations

Eulachon are particularly important to First Nations people. They are eaten fresh, dried, smoked, salted, and frozen whole. However, the product of greatest cultural, nutritional, social and economic value is the 'grease' rendered from the fish. Eulachon grease was produced by First Nations groups of the Central and the Northern Coasts of BC and by some First Nations groups in Alaska. The First Nations south of Knight Inlet did not produce grease but harvested the Eulachon for smoking and for fresh consumption. Eulachon grease is produced from aged or rotted fish that are cooked until the oil of the fish has separated and can be removed. The 'grease' is a very nutritious food that is high in unsaturated fats and is superior at providing vitamin A, E and K when compared to other common fat sources (Kuhnlein *et al.* 1982). The grease is used as a staple in many First Nations diets and is distributed widely in potlatches, traded with neighbouring Nations and relied upon as a medicine. The importance of grease is best signified by the ancient trade routes used to link the coastal First Nations with the interior First Nations. These routes are famously referred to as "Grease Trails" as the heaviest traffic occurred during the Eulachon season to trade for the highly sought after grease (Collison 1941).

As documented in this report, First Nations fisheries for Eulachon have declined by at least 90% from historical levels. The Nass River produced catches in the order of 2100 t annually around 1840. The Kitimat River yielded between 100 – 500 t annually in the early 1900s. The Bella Coola region had a large but undocumented historical fishery. The Kingcome and Klinaklini Rivers in the Johnstone Strait region produced in the order of 100 t annually. Currently, the Nass River has fisheries for approximately 200 t annually and the fisheries in the Johnstone Strait yield approximately 10 t annually. Runs in the other formally important rivers have virtually ceased.

Ecosystem impacts

A potentially serious side-effect of the decline of Eulachon in the Fraser River is a deleterious impact on endangered White Sturgeon, especially juveniles that scavenge (and may rely on) post-spawning moribund or dead Eulachon as a source of food after a long winter (Sturgeon Society data cited by Pickard and Marmorek 2007).

EXISTING PROTECTION, STATUS, AND RANKS

Eulachon are not listed by the IUCN.

On March 16, 2010, the United States announced that it was listing the southern Eulachon distinct population segment as threatened under its *Endangered Species Act* on March 10, 2010 (http://www.nwr.noaa.gov/Other-Marine-Species/Eulachon.cfm).

The province of British Columbia 'blue' listed Eulachon in 2000 and maintained that listing when it was reviewed in 2004.

Since 1995 Fisheries and Ocean Canada has taken five specific activities to protect Eulachon: (i) suspension of commercial Eulachon fisheries in the Fraser River; (ii) the suspension of dredging during the Eulachon spawning season in the lower Fraser River; (iii) the closure of the shrimp fishery in Queen Charlotte Sound, the offshore area of central British Columbia; (iv) imposition of 'Eulachon action levels' by DFO management that warn of possible shrimp fishing closures when the cumulative shrimp bycatch level is achieved; (v) imposition of mandatory BRDs installed in shrimp trawls.

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Tom Therriault, Pacific Biological Station, Nanaimo, BC

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Megan Moody is a First Nation's woman from the Nuxalk Nation, Bella Coola, BC. She completed a BSc at the University of Victoria with a major in Biology in April 2000 and an MSc in Resource Management and Environmental Studies at the University of British Columbia's Fisheries Centre in May 2008. The MSc thesis was titled "Eulachon past and present". Megan Moody's extensive fisheries work with First Nations groups includes projects specifically on Eulachon; including field sampling and co-management and design of the 2002-2009 Bella Coola Eulachon assessment studies. She has written a number of technical papers for the Nuxalk Nation Fisheries Department from 2003-2007 on the Bella Coola River Eulachon studies.

Current position: Central Coast Data Management Advisor/AAROM Coordinator
Employer: O(W)-K-N-TC (Wuikinuxv-Kitasoo-Nuxalk Tribal Council)

Doug Hay completed undergraduate work in Zoology at UBC and graduate work in fisheries completing a PhD in 1974. His career included four years of teaching at universities, two years as a consultant in Nova Scotia, and thirty years with the Fisheries and Oceans Science Branch at the Pacific Biological Station, Nanaimo. During that time he authored over 200 reports concerned mainly with small pelagic fishes, including Eulachon. He also served in scientific societies (PICES, where he chaired the Fisheries Science Committee of two years) and participated in academic work as a member of student advisory committees, and occasional lecturer. Subsequent to retiring from DFO in 2006 he spent two years teaching fisheries ecology at Pusan National University in Busan, Korea and has been active with private consulting and publishing.

Present position; Independent consultant and scientist emeritus, Pacific Biological Station, Nanaimo BC

COLLECTIONS EXAMINED

None.

Appendix 1. Detailed review of the distribution, catch and related biological information for United States rivers.

Alaska

Approximately 35 rivers in Alaska may support Eulachon returns (Kitto 2000). The largest are: the Unuk, Stikine, Taku, Mendenhall and Chilkat Rivers in Southeastern Alaska, the Situk River near Yakutat, the Copper River near Cordova and the Kenai, Susitna and Twentymile Rivers in Cook Inlet (Bartlett and Dean 1994). The Eulachon in the southeastern rivers return as early as April, while in the central Alaskan rivers, they commonly return in May (Bartlett and Dean 1994).

The Copper River in Prince William Sound is one of the larger Eulachon rivers in Alaska (Bartlett and Dean 1994). The Copper River Delta, from the west to east, consists of five other known Eulachon spawning systems: the Eyak River, Ibeck Creek, the Scott River, Alaganik Slough and the Martin River. The Eulachon return to this region in several waves, with the largest wave commonly returning during May; however, in recent years Eulachon have been found as early as January and as late as June 30.

The Upper Cook Inlet area has two large Eulachon runs, the Susitna and the Kenai and a smaller run that returns to the Twentymile River. Portage Creek and the Placer River, both adjacent to the Twentymile River, were reportedly fished for Eulachon in the past (Spangler *et al.* 2003). Eulachon start to return to Cook Inlet from mid-May to mid-June (Shields 2005).

The Chilkat, Chilkoot, Taiya, and Ferebee Rivers are all Eulachon rivers that flow into Lynn Cannel. The Chilkat River supports one of the larger Eulachon runs in Southeastern Alaska (Betts 1994). The Chilkoot River flows parallel to the Chilkat River but its run is restricted to the lower part of the river, as the river is short. Both of these rivers support harvests by the Chilkat and Chilkoot Tlingit people and local sports fishers. The Taiya River Eulachon run is reportedly small thus is not fished. The Eulachon arrive in these rivers between mid- and late May and are harvested for one to two weeks (Mills 1982). The Eulachon commonly arrive a few days earlier in the Chilkat River (Betts 1994).

Southeastern Alaska has approximately sixteen Eulachon rivers (Willson *et al.* 2006). Only the Unuk River, the Chilkat/Chilkoot Rivers and the Berners Bay rivers have information on Eulachon. Since 2001, the Forest Service has conducted aerial surveys, and monitored yearly returns and harvest by qualified subsistence and personal use fishers. The Eulachon return to the Unuk River during the middle of March. The majority of subsistence and personal use catch has come from the Hooligan River, a tributary to the Unuk River. The Hooligan River is perceived by local residents to have the most consistent run from year to year when compared to other areas of the Unuk estuary (Tisler and Spangler 2003). Prior to 2001, the Alaskan Department of Fish and Game monitored the Unuk run on a very limited basis (USFS 2006). In 2002 and 2003, Eulachon were observed in the Hooligan River. Also, in 2003, they were observed in the

Klahini River but not in the Chickamin. By 2004, the Eulachon run was "well below average" and only small schools were observed in the Hooligan River, with a total harvest of 0.73 t of fish (USFS 2006). Twenty years ago, Eulachon harvests from the Unuk River ranged from 7 to 14 t per year. The 2005 season saw no improvement and no harvest, as the run was reportedly "very poor overall" and "absent on the Unuk River" (Morphet 2005). The 2006 Eulachon run was "nearly absent" as only 34 male Eulachon and 1 dead female were seen in the area (USFS 2007). It is unknown why the Eulachon have not returned in good numbers to this area for the past three seasons.

Washington, Oregon and California

There are approximately twenty rivers within the states of Washington and Oregon that have had Eulachon spawning runs (Willson *et al.* 2006). Within Washington State, the Bear, Naselle, Nemah, Wynoochee, Quinault, and Queets rivers may support Eulachon runs. Within the Columbia River system Eulachon spawning may occur in the Columbia River mainstem and tributaries: Grays, Skamokawa, Elochoman, Cowlitz, Kalama, Lewis and Sandy.

The Columbia River is the largest Eulachon river in both of these states, and possibly the largest Eulachon run in the world (Washington and Oregon Department of Fish and Game (WDFW & ODFW 2005). The lower Columbia River separates the states of Washington and Oregon, therefore the Columbia mainstem is managed jointly by both states. The Eulachon enter the lower Columbia River in early to mid-January and peak in abundance during February, in the tributaries (WDFW & ODFW 2004). The Eulachon travel annually up the Columbia River mainstem as far as the Bonneville Dam; however, prior to the dam being built, they were known to travel as far as the Hood River (Smith and Saalfeld 1955), approximately 35 km farther upstream. The Eulachon are also known to return, although less regularly, to the Columbia River tributaries: Grays, Skamokawa, Cowlitz, Kalama, Lewis and Sandy rivers.

Up until the mid-1990s, commercial landings were quite stable in the Columbia River, with the exception of 1984, which was thought to have been affected by the 1982-83 El Niño event (WDFW & ODFW 2004). Even though the Columbia River catches declined suddenly in 1993 historical documents indicate that major declines have occurred in the past: "*[Eulachon] was once abundant in the Columbia, but that stream being now Disturbed by the traffic of steamers, it is only now in exceptional years that they are caught there in any quantity (Brown 1868).*" An earlier report states: *"Formerly resorting in enormous shoals to the estuary of the Columbia River, [Eulachon] disappeared suddenly about the year 1837, and continued to absent itself for many years, until recently when it suddenly reappeared in shoals as numerous as of yore (Canada 1877)."*

A 1999 petition to list the Columbia River Eulachon under the *Endangered Species Act* was denied by the National Marine Fisheries Service, and an ESA status review was not conducted due, in part, to a finding that the petition did not present substantial evidence as to why the Columbia River Eulachon were considered distinct from other Eulachon. A listing was not proposed "due to the lack of adequate information for stock status determination" (WDFW & ODFW 2004). The runs to the Columbia tributaries have also failed in some years. The Cowlitz River Eulachon were reported to be scarce (1938, 1949, 1959 and 1979) and absent (1950-51, 1965 and 1977) in some years (Hinrichson 1998). The Sandy River run also disappeared in the past (1988 to 1999); however, in 2000 the run returned and in 2003 there were commercial landings for the first time since the 1980s (WDFW & ODFW 2004). The Columbia River Eulachon returns remained at record lows between 1994 and 2000, but improved CPUE in the commercial fishery and large larval abundance suggested the abundance had improved between 2000 and 2003 (WDFW & ODFW 2005). However, poor returns were again seen in 2004 and 2005, with record low commercial landings in 2005 (0.09 t) (WDFW & ODFW 2005). The 2006 season was considered "poor" with only slight improvements in commercial catch (5.94 t) (WDFW & ODFW 2005). However, these are extremely small when compared to historic catches.

Historically the major Eulachon rivers in California were the Klamath River in Del Norte County and the Mad River and Redwood Creek in Humboldt County (Odemar 1964). There are incidental reports of Eulachon returning to the Smith River; however, these runs were not large or regular (Moyle *et al.* 1995). Eulachon runs in northern California start in December and January and peak in abundance during March and April (Larson and Belchik 1998). In California, Eulachon were never commercially important, yet they were fished recreationally and were of great importance to the Yurok Tribe. The only reported commercial catch occurred in 1963 when a combined total of 56,000 lbs (25 t) was landed from the Klamath River, the Mad River and Redwood Creek (Odemar 1964).

Until the mid-1970s, the Mad River and Redwood Creek had heavy Eulachon runs, (Moyle *et al.* 1995), but the Klamath run has been the largest in California (Fry 1973) and last had a "noticeable" run during the late 1980s, according to Yurok tribal elders (Larson and Belchik 1998). One member of the Yurok tribe reported that the last large run of Eulachon occurred in 1988, with a smaller run in 1989, and only a "few" were caught in 1990 and 1991 (Larson and Belchik 1998). During the 1996 season, the Yurok Tribal Fisheries Program attempted to capture Eulachon in the Klamath River, spending a total of 119 staff hours, with no success. However, one Yurok tribal member captured one Eulachon in March 1996 while fishing for lamprey (*Lampetra tridentate*) (Larson and Belchik 1998). Thus the Eulachon have virtually disappeared from this area since the early 1990s.

Appendix 2. Midwater trawl information and data sources.

Bibliography and list of Technical, (TR), Manuscript (MR) and Data Reports (DR), from the Department of Fisheries and Oceans or the Fisheries Research Board of Canada, that were examined for analyses of Eulachon offshore distribution as incidental capture from midwater trawls. Information on location, depth and catch quantity was extracted on the offshore catches of Eulachon, which usually was incidental to a different target species. All of the reports were published as part of a continuing series of publications by the Fisheries Research Board of Canada (to 1972) of the later Department of Fisheries or Dept. of Fisheries and Oceans. Reports numbers which contained some information on Eulachon are followed with full citations. The reports are listed in numerical order of publication which approximates the time of the cruise. The following list shows the Report Number and full citation – if report contains reference to eualchon catches. Reports that contained no reference to Eulachon are listed only as report numbers.

Technical reports

TR0011	Taylor, F.H.C. 1967. Midwater trawl catches from Queen Charlotte Sound and the open ocean adjacent to the Queen Charlotte Islands. Fish. Res. Board. Can. Tech. Rep. No. 11.
TR0022	-
TR0046	-
TR0062	-
TR0081	Harling, W.R., D. Davenport, L.E. McLeod, and S.J Westrheim. 1968. G.B. REED Groundfish Cruise No. 68-2 April 2-June 11, 1968. Fish. Res. Board. Can. Tech. Rep. 81.
TR0117	-
TR0132	-
TR0140	Taylor, F.H.C. 1969. The British Columbia Offshore Herring Survey 1968 Fish. Res. Board. Can. Tech. Rep. No. 140.
TR0174	Taylor, F.H.C. 1970. The British Columbia Offshore Herring Survey 1969-1970. Introduction, Methods, and Report on Cruises SK 69-1, -2, and -3. Fish Res. Board. Can. Tech. Rep. No. 174.
TR0177	Taylor, F.H.C., L.W. Barner, and D.C. Miller. 1970. The British Columbia Offshore Herring Survey, 1969-1970. Report on Cruises SK 69-4, -5, and -6. Fish. Res. Board. Can. Tech. Rep. No. 177.
TR0183	Taylor, F.H.C., L.W. Barner, and D.C. Miller. 1970. The British ColumbiaOffshore Herring Survey, 1969-1970. Report on Cruises SK 69-7, -8, -9, and -10. Fish. Res. Board. Can. No. 183
TR0190	Taylor, F.H.C., L.W. Barner, and D.C. Miller. 1970. The British Columbia Offshore Herring Survey, 1969-1970. Report on Cruises SK 70-1, -2, and 3. Fish. Res. Board. Can. No. 190.
TR0210	

TR0213	Taylor, F.H.C., L.W. Barner, and D.C. Miller. 1970. The British Columbia Offshore Herring Survey, 1969-1970. Report on Cruises SK 70-4, -5, -6 and -7. Fish. Res. Board. Can. No. 213.
TR0216	
TR0221	Harling, W.H., D. Davenport, M.S. Smith, and R.M.Wowchuk. 1970. G.B. REED Groundfish Cruise No. 70-3, September 9-25, 1970. Fish. Res. Board. Can. Tech. Rep. No. 221.
TR0269	
TR0290	Harling, W.R., D. Davenport, M.S. Smith, R.M. Wowchuk, and S.J. Westrheim. 1971. G.B. REED Groundfish Cruise No. 71-3, October 1-29, 1971. Fish. Res. Board. Can. Tech. Rep. No. 290.
TR0328	
TR0345	
TR0410	Westrheim, S.J., W.R. Harling, D. Davenport, M.S. Smith, and A.C. Phillips. 1973. G.B. REED Groundfish Cruise No. 73-1, June 5-July 26, 1973. Fish. Res. Board. Can. Tech Rep. No. 410.
TR0424	
TR0478	
TR0496	Barner, L.W., and F.H.C. Taylor. 1974. The offshore Herring survey off southwest Vancouver Island in 1972 and 1973. Report on G.B. REED cruises GBR 72-4 (October 18-November 2), GBR 73-1 (January 17-31), and GBR 73-2 (March 13-29). Fish. Mar. Ser. Res. Dev. Tech. Rep. 496: 69 p.
TR0497	Westrheim, S.J., W.R. Harling, D. Davenport, and M.S. Smith. 1971. G.B. REED groundfish cruise no. 74-4, September 4-25, 1974. Fish. Mar. Ser. Res. Dev. Tech. Rep. 497: 37 p.
TR0503	Taylor, F.H.C., and L.W. Barner. 1974. A Herring Survey of Juan de Fuca Strait in 1971. Report on A.P KNIGHT Cruises APK 71-3, -4, -5, -6 and -7 (July 22-December 12). Fish. Mar. Ser. Tech. Rep. No. 503.
TR1333	Taylor, F.H.C. 1984. Distribution and abundance of Herring and other pelagic fish off the west coast of Vancouver Island in September, 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1333: 43 p.

Manuscript Reports

MR0767
MR0768
MR0932
MR0934
MR0977

MR1007	Westrheim, S.J. 1968. Report on trawling operations of the Canadian research vessel G.B. REED from Chirikof Island to Unalaska Island, July 27-August 22,1964. Fish. Res. Board. Can. MS Rep. 1007
MR1063	
MR1078	
MR1089	
MR1101	
MR1106	
MR1117	
MR1152	
MR1220	
MR1226	Barner, L.W. and F.H.C. Taylor. 1972. The offshore Herring survey off southwest Vancouver Island in 1971. Report on A.P. Knight cruises APK 71-1 (January 18-February 4) and APK 71-2(March 16-April1). Fish. Res. Board. Can. MS Rep. 1226
MR1231	
MR1238	Smith, M.S. and S.J. Westrheim. 1973. A.P. Knight Groundfish Cruise No. 73-1, February 13-14, 1973. Fish. Res. Board. Can. MS Rep. 1238
MR1247	
MR1252	Taylor, F.H.C., and L.W. Barner. 1973. The offshore Herring survey off Southwest Vancouver Island in 1972. Report on G.B. REED Cruises GBR 72-1 (January 13-28), GBR 72-2 (March 6-24), and GBR 72-3 (April 11-27). Fish. Res. Board. Can. MS Rep. No.1252
MR1260	
MR1290	
MR1299	
MR1301	
MR1302	
MR1315	
MR1318	
MR1336	
MR1367	Westrheim, S.J., W.R Harling, D. Davenport, and R.M. Wowchuk. 1975. G.B. REED Groundfish Cruises 75-1 (April 8-24) and 75-2 (July 8-24). Fish. Res. Board. Can. MS Rep. No. 1367.
MR1371	
MR1605	

MR1651	R.J. Beamish, G.A. McFarlane, K.R. Weir, M.S. Smith, J.R. Scarsbrook, A.J. Cass, and C. Wood. 1982. Observations on the biology of Pacific hake, walleye pollock and spiny dogfish in the Georgia Strait, Juan deFuca Strait and off the west coast of Vancouver Island and the United States. Arctic Harvester July 13-29, 1976. Can. MS Rep. Fish. Aquat. Sci. 1651: 150 p.
MR1682	Taylor, F.H.C., and R. Kiesser. 1982. Distribution and abundance of Herring and other pelagic fish off the west coast of Vancouver Island in September, November, 1980, and March, 1981, and in the Strait of Georgia in November, 1980. Can. MS Rep. Fish. Aquat. Sci. 1682: vi + 167 p.
MR1697	Shaw, W., G.A. McFarlane, and R.J. Beamish. 1982. An examination of the the biology and distribution of Pacific hake, walleye pollock and spiny dogfish in the Stait of Georgia. R/V G.B. REED, May 25-June 18, 1976. Can. MS Rep. Fish. Aquat. Sci. 1697: v + 240 p.
MR1754	
MR1917	
MR1924	Rosenfeld, L., V. Haist, and D. Chalmers. 1987. Distribution and abundance of Pacific Herring off the west coast of Vancouver Island, September 26-October 30, 1984. Can. Ms Rep. Fish. Aquat. Sci. 1924: 23 p.
MR1940	
MR1996	
MR1997	
MR2012	Shaw, W., R. Tanasichuk, D.M. Ware, and G.A. McFarlane. 1989. Species interaction and biological survey of Pacific hake, sablefish, spiny dogfish and Pacific Herring off the southwest coast of Vancouver Island. F/V CALEDONIAN, August 12-25, 1986. Can. MS Rep. Fish. Aquat. Sci. No. 2012: 134 p.
MR2040	
MR2056	
MR2108	

Data Reports

DR0003	
DR0011	
DR0021	Westrheim, S.J., B.M. Leaman, W.R. Harling, D. Davenport, M.S. Smith, and R.M. Wowchuk. 1976. G.B. REED Groundfish Cruise No. 76-3, September 8-27 1976. Fish. Mar. Serv. Data Rep. 21
DR0040	
DR0044	Barner, L.W., and F.H.C. Taylor. 1977. Herring survey off the southwest Vancouver Island in 1973 cruise GBR 73-3. Fish. Mar. Serv. Data Rep. 44: 17 p.

DR0048	Beamish, R.J., M. Smith, and R. Scarsbrook. 1978. Hake and pollock study, Georgia Strait cruise, G.B. REED January 6-February 21, 1975. Fish. Mar. Serv. Data Rep. 48: 206 p.
DR0051	
DR0066	Barner, L.W., and F.H.C. Taylor. 1978. Midwater trawl tows and catches made on G.B. REED cruises 74-1, -2, and GBR 75-4, -5 off the southwest coast of Vancouver Island. Fish. Mar. Serv. Data Rep. 66: 47 p.
DR0071	Weir, K.R., R.J. Beamish, M.S. Smith, and J.R. Scarsbrook. 1978. Hake and pollock study, Georgia Strait bottom trawl cruise G.B. REED February 25-March 13, 1975. Fish. Mar. Serv. Data Rep. 71: 153p.
DR0078	
DR0088	Barner, L.W., and F.H.C. Taylor. 1978. Midwater trawl tows and catches made on ARCTIC HARVESTER 76-2, 77-1 and G.B. REED 77-1, 77-2 off the southwest coast of Vancouver Island. Fish. Mar. Serv. Data Rep. 88: 91 p.
DR0106 !	Barner, L.W., F.H.C. Taylor, and A. Bennett. 1978. Midwater trawl tows and catches made on ARCTIC HARVESTER Cruise 78-1 and G.B. REED Cruise 78-1, Queen Charlotte Sound. Fish. Mar. Serv. Data Rep. 106: 37 p.
DR0110	Barner, L.W., J. Selsby, and F. Mottl. 1978. Rockfish survey off the coast of the Queen Charlotte Islands made on ARCTIC HARVESTER hydroacoustic cruise 78-2, May 11-June 2, 1978. Fish. Mar. Serv. Data Rep. 110: 86 p.
DR0130	Miller, D.C., 1978. Report on Cruise 78-1 of CANADIAN NO. 1, October 22-November 3, 1978. Fish. Mar. Serv. Data Rep. 130: 15 p.
DR0135	
DR0138	Barner, L.W., F.H.C. Taylor, D.M.A. Bennett and S. Farlinger. 1979. Midwater and bottom trawl tows and catches made on M.V. BLUE WATERS BW 78-3, October 3-23, 1978 in Queen Charlotte Sound. Fish. Mar. Serv. Data Rep. 138: 72 p.
DR0179	Westrheim, S.J., R.P. Foucher, W.R. Harling, and W. Shaw. 1980. G.B. REED Groundfish Cruise No. 79-4, June 26-Julu 13, 1979. Can. Data Rep. Fish. Aquat. Sci. 179: 73 p.
DR0187	
DR0191	
DR0206	Barner, L.W., F.H.C. Taylor, J.M. Thompson, and W.T. Ryan. 1980. Midwater trawl tows and catches made on G.B. REED Cruise, GBR79-7 off southwest coast of Vancouver Island, October 29-November 16, 1979. Can. Data Rep. Fish. Aquat. Sci. 206: 57 p.
DR0225	Cass, A.J., R.J. Beamish, M.S. Smith, and K. Weir. 1980. Hake and Pollock study, Georgia Strait cruise, G.B. REED, January 13-28, 1976. Can. Data Rep. Fish. Aquat. Sci. 225: 88 p.

DR0251	Thompson, J.M. 1981. Walleye pollock study in the Queen Charlotte Sound and Dixon Entrance during September 21-29, 1979: M/V ARCTIC HARVESTER. Can. Data Rep. Fish. Aquat. Sci. 251: 77 p.
DR0294	
DR0310	
DR0314	
DR0315	
DR0333	
DR0339	McFarlane, G.A., W. Shaw, J.M. Thompson, J.R. Scarsbrook, M.S. Smith, and K.L. Best. 1982. Data collected during hake and pollock assessments, Georgia Strait cruises, February 20-May 2, and July 3,1981. Can. Data Rep. Fish. Aquat. Sci. 339: iii + 456 p.
DR0346	
DR0352	McCarter, P.B., L.W. Barner, and F.H.C. Taylor. 1982. Midwater trawl tows and catches made on C.G.S G.B REED Cruise GBR81-3, M/V HOWE BAY Cruise HB81-1, and M/V MARWOOD Cruise MW81-1 off the southwest coast of Vancouver Island March 9-27, 1981. Can. Data Rep. Fish. Aquat. Sci. No. 352: iii + 113 p.
DR0372	
DR0398	Shaw, W., G.A. McFarlane, and R.J. Beamish. 1982. Biological study of Pacific hake, walleye pollock and spiny dogfish in the Stait of Georgia. R/V G.B. REED, March 22-April 2, 1976. Can. Data Rep. Fish. Aquat. Sci. No. 398: iv + 76 p.
DR0430	
DR0445	
DR0458	Barner, L.W., R. Kieser and T.J. Mulligan. 1984. A hydroacoustic survey for Pacific hake on the continental shelf off British Columbia and Washington from 48 to 49 degrees north latitude: August 22 to September 8, 1983. Can. Data Rep. Fish. Aquat. Sci. 458: 98 p.
DR0488	
DR0491	
DR0500	
DR0526	
DR0543	
DR0611	
DR0615	
DR0602	
DR0651	
DR0656	
DR0708	
DR0716	

DR0783
DR0866
DR0920
DR0925
DR0925

Appendix 3. Comparison of CPUE in the Fraser River between two periods: 1941-1953 and 1995-2004 (shown in Fig. 6b).

The following is a brief analysis, prepared specifically for this report, that attempts to compare present levels of abundance in the Fraser River with that of the past. There are no estimates of spawning biomass for the Fraser River prior to 1995, but Ricker *et al.* (1954) made estimates of catch and fishing effort, based on the duration and amount of gear fished. Ricker's analysis may provide an approximate comparison with the recent test fishing conducted for DFO and reported by Hay *et al.* (2003).

Systematic test-fishery catches were conducted in the New Westminster area from 1995-2004, except 1999. The catches are made daily using identical gillnet gear (mesh size 3.18 cm or 1.25 inches, 50 fathoms or 92 m long and 380 meshes deep, fished at the same location (New Westminster), for the same duration (15 minutes), and at the same stage of tide (low slack at New Westminster). All of the catch was sorted by sex, counted, weighed and a biological sample was taken for further analysis. Catch numbers are tallied each week.

The data from this test fishery (Appendix Tables 1-3) were compared with catches made between 1941-1953, when the Eulachon catch and effort was monitored carefully (Ricker *et al.* 1954). In those years the total weekly catches were recorded as well as total fishing effort, measured as hundreds of 'fathom hours'. The lengths and depths of Eulachon gillnets were measured in fathoms (~6 ft or 1.82 m). The effort was recorded as the number of hours that each unit amount of net (100 square fathoms) was fished. This estimate was made weekly, for each of the 8-9 weeks of the fishery between 1941 and 1953. The effort was summed as the numbers of 100-fathom-hours fished each week. The weeks were always started as week 1, on the last (or near-last) Sunday in March. Ideally it would be preferable to compare catches and CPUE by the day of the year, but this is not possible because the weekly periods started at slightly different times each year. Curiously, in some years the weekly fishing period (week 1) began about March 23, and in other years the week starts on March 30 (never March 31). Therefore there is a variance of about 7 days when the fishing and CPUE is compared over the two time periods.

The more recent test fishery was conducted only for short (15 minute) periods each day. The test net was 50 fathoms long and measured 380 meshes (1.25 inches per mesh) deep. The fishing depths of the commercial nets described by Ricker *et al.* 1954 (in their Table 1) were 200 meshes and the depth of such a 200 mesh net was 2.2 fathoms. The depth of the test net, at 380 meshes, was about 4.2 fathoms (380/200 x 2.2 fathoms). Therefore, during the test sets the unit of measurement (100 fathoms hours) was estimated at 210 square fathoms fished for 0.25 hours, so in units of 100-fathom-hours (fh), each set was 0.52 fh.

The commercial fishery (from 1941-1953) recorded catch in total lbs whereas the test fishery (from 1995-2005) recoded total number of individuals. The mean weight of approximately 3900 Eulachon captured in test fishery was 42 g, which is almost exactly

0.1 lbs. per fish. Therefore the catches of the test fishery were converted to weights by multiplying the number of captured fish by 0.1 lbs per fish.

The test fishery was conducted daily so further adjustment was required to compare the 1941-1953 commercial catch CPUE with that of the test fishery. This was done in two ways: one by adjusting the format of the older data to match the recent data, and vice versa. The estimated DOY (day of the year) of the 1941-1953 commercial fishery was estimated from an Appendix table in Ricker *et al.* (1954), by determining the DOY for the start of each week (and adjusting for leap years). Data sets for both periods were divided into weekly periods.

When the reconstructed CPUE are aggregated within each period and then compared and contrasted between two periods (1941-1953 and 1995-2005) the following trends emerge: (i) the daily CPUE (in lbs. per hour) estimates are roughly similar with maximums between 100 and 300 lbs./hour); (ii) the duration of the fishery was longer in the 1941-1953 period; (iii) the timing of the run, judged by the dates of maximal catches, is earlier in the recent period (1995-2005) period (Fig. 7b).

Table A1. The weekly Fraser River catch and effort data for 1941-1953, from Appendix Table 1, Ricker *et al.* 1954. The column 'C-E-C/E' shows the catch, effort and catch per unit effort (C/E) for each of the years, adjusted for leap year variation).

	C-E-C/E	Week Number number (from -1 to 9)											
		-1	0	1	2	3	4	5	6	7	8	9	Total
1941	C	125	1111	4352	6404	24456	78494	16627	599	0 *	*		132168
30-Mar	E	65.6	202.3	440.7	619	422.8	583.3	244.9	57.4	0 *	*		2636
Day 89	C/E	1.91	5.49	9.88	10.35	55.23	134.57	73.93	10.44	0 *	*		50.14
DOY		*82*	*89*	*96*	*103*	*110*	*117*	*124*	*131*	*138*			
1942	C	0	0	70	4983	15991	91712	84182	16848	0 *	*		213786
29-Mar	E	0	0	10.5	155.8	282.2	412.3	383.8	165.1	0 *	*		1409.7
Day 88	C/E	0	0	6.67	31.98	56.67	222.4	219.34	102.05	0 *	*		151.65
DOY		81	88	95	102	109	116	123	130	137			
1943	C	0	0	0	5332	34592	55326	108036	6870	0 *	*		210156
28-Mar	E	0	0	0.2	71.9	407.3	411.6	407.7	59	0 *	*		1357.7
Day 87	C/E	0	0	0	74.16	84.93	134.42	264.99	116.44	0 *	*		154.79
DOY		*80*	*87*	94	101	108	115	122	129	136			
1944	C	0	88	189	979	3559	39790	73329	14769	30 *	*		132733
26-Mar	E	0	23.4	55.6	145	422.1	660.6	511	199.5	3 *	*		2020.2
Day 86	C/E	0	3.76	3.4	6.75	8.43	60.23	143.5	74.03	10 *	*		65.7
DOY		*79*	*86*	*93*	*100*	*107*	*114*	*121*	*128*	*135*			
1945	C	0	36	56	1238	5478	24803	93898	70925	8977 *	*		205411
25-Mar	E	0	10.2	20.7	103.5	308.8	680.8	853.2	763.6	39.9 *	*		2780.7
Day 84	C/E	0	3.53	2.71	11.96	17.74	36.43	110.05	92.88	224.99 *	*		73.87
DOY		*77*	*84*	*91*	*98*	*105*	*112*	*119*	*126*	*133*			
1946	C	0.5	0	9	249	754	3634	69905	78897	16770 *	*		170218.5
24-Mar	E	1.1	0	6.6	37.8	121	161.1	701.5	409.1	32.9 *	*		1471.1
Day 83	C/E	0.45	0	1.36	6.59	6.23	22.56	99.65	192.86	509.73 *	*		115.71
DOY		*76*	*83*	*90*	*97*	*104*	*111*	*118*	*125*	*132*			
1947	C	0	0	244	1306	34749	167079	80777	761	0 *	*		284916
30-Mar	E	0	0	35.2	73.3	269.3	595.6	254.1	5.2	0 *	*		1232.7
Day 89	C/E	0	0	6.93	17.82	129.03	280.52	317.89	146.35	0 *	*		231.13
DOY		*82*	*89*	*96*	*103*	*110*	*117*	*124*	*131*	*138*			
1948	C	0	0	478	1212	5018	118561	215135	22636	0 *	*		363042
30-Mar	E	0	0	85.4	199.7	208.2	1185.2	1360.2	178.6	0.2 *	*		3217.5
Day 90	C/E	0	0	5.6	6.07	24.1	100.03	158.16	126.74	10 *	*		112.83
DOY		*83*	*90*	*97*	*104*	*111*	*118*	*125*	*132*	*139*			
1949	C	0	0	0	335	10960	55872	215204	15796	0 *	*		298167
27-Mar	E	0	0	0	25.4	570.3	1091.3	1107.1	109.7	0 *	*		2903.8
Day 86	C/E	0	0	0	13.19	19.22	51.2	194.39	143.99	0 *	*		102.68
DOY		79	86	93	100	107	114	121	128	135			
1950	C	0	0	0	12	1983	38922	119487	28241	30 *	*		188745
26-Mar	E	0	0	0	4.7	246.1	1555.1	2697.9	714.5	0.9 *	*		5219.2
Day 85	C/E	0	0	0	2.55	8.06	24.07	44.29	39.53	33.33 *	*		36.16
DOY		78	85	92	99	106	113	120	127	134			
1951	C	0	0	0	118	257	7390	53980	197547	52022 *	*		311314
25-Mar	E	0	0	0	25.4	29.2	278.3	742.6	1336.3	359 *	*		2770.8
Day 84	C/E	0	0	0	4.65	8.8	26.55	72.69	147.83	144.91 *	*		112.36
DOY		77	84	91	98	105	112	119	126	133			140
1952	C	0	0	0	111	12867	130331	393916	206915	0 *	*		744140
30-Mar	E	0	0	0	70.5	495.3	2031.4	2555.7	1230.6	0 *	*		6383.5
Day 90	C/E	0	0	0	1.57	25.98	64.16	154.13	168.14	0 *	*		116.57
DOY		83	90	97	104	111	118	125	132	139			
1953	C	0	0	55	0	3866	42972	137274	32020	1760 *	*		217947
29-Mar	E	0	0	5.8	0	96.3	479.3	710.4	63.6	3.4 *	*		1358.8
Day 88	C/E	0	0	9.48	0	40.15	89.65	193.23	503.46	517.65 *	*		160.4
DOY		*82*	*88*	*94*	*100*	*106*	*112*	*118*	*124*	*130*			

Table A2. The 1995-2004 Fraser River test fishery data adjusted to match the commercial data collected from 1941-1953. The column 'C-E-C/E' shows the catch, effort and catch per unit effort (C/E) for each of the years.

Date_1 DOY_1	C-E-C/E	0	1	2	3	4	5	6	7	8	9	
1995-wt_1	C	0	16.4	10.4	231	815.5	48.9	18.2	24.4	0.6	0	1165.4
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	0.00	31.54	20.00	444.23	1568.27	94.04	35.00	46.92	1.15	0.00	224.12
1996-wt_1	C	1.1	24.6	15	226.2	1771.1	905.6	814.7	435.1	14.1	0	4207.5
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	2.12	47.31	28.85	435.00	3405.96	1741.54	1566.73	836.73	27.12	0.00	809.13
1997-wt_1	C	16.9	28.3	47.2	62.3	83.9	72.6	0.6	0	0	0	311.8
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	32.50	54.42	90.77	119.81	161.35	139.62	1.15	0.00	0.00	0.00	59.96
1998-wt_1	C	5.2	33.5	14.6	6.5	41.9	102.5	1.1	0	0	0	205.3
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	10.00	64.42	28.08	12.50	80.58	197.12	2.12	0.00	0.00	0.00	39.48
2000-wt_1	C	0	3.4	9.6	12	125.5	465.7	579.4	191.7	59.1	11.5	1457.9
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	0.00	6.54	18.46	23.08	241.35	895.58	1114.23	368.65	113.65	22.12	280.37
2001-wt	C	0	0	0.6	1.9	23.5	628.6	564.9	213.6	42.3	0	1475.4
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	0.00	0.00	1.15	3.65	45.19	1208.85	1086.35	410.77	81.35	0.00	283.73
2002-wt	C	13.5	43.9	20.7	30.1	186.3	367.5	102.9	10.9	0	0	775.8
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	25.96	84.42	39.81	57.88	358.27	706.73	197.88	20.96	0.00	0.00	149.19
2003-wt	C	0	18.5	28	279.7	663.9	131.8	114.5	6.9	0	0	1243.3
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	0.00	35.58	53.85	537.88	1276.73	253.46	220.19	13.27	0.00	0.00	239.10
2004-wt	C	0	3.3	8	13.1	19.1	20.6	24.5	0	0	0	88.6
	E	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	5.2
	C/E	0.00	6.35	15.38	25.19	36.73	39.62	47.12	0.00	0.00	0.00	17.04

Table A3. Comparison of the annual CPUE (lbs. of catch per 100 square fathoms fished per hour) by year between 1941-1953 and 1995-2005. The data are roughly similar except for 1996, which stands out as an exceptional year. The CPUE for 2004 was the lowest ever recorded.

1943 C/E	154.8
1944 C/E	65.7
1945 C/E	73.9
1946 C/E	115.7
1947 C/E	231.1
1948 C/E	112.8
1949 C/E	102.7
1950 C/E	36.2
1951 C/E	112.4
1952 C/E	116.6
1953 C/E	160.4
1995 C/E	224.1
1996 C/E	809.1
1997 C/E	60.0
1998 C/E	39.5
2000 C/E	280.4
2001 C/E	283.7
2002 C/E	149.2
2003 C/E	239.1
2004 C/E	17.0